ALL ABOUT AIRCRAFT OF TODAY

BY THE SAME AUTHOR

"All About Treasures of the Earth"

"All About Inventions and Discoveries"

"Railway Wonders of the World"

"Aeroplanes and Dirigibles of War"

etc. etc. etc.

From a picture by G. H. Davis.

DROPPING THE MAIL.

All About Aircraft of Today.

By

FREDERICK A. TALBOT

With a Coloured Plate and numerous Black-and-White Illustrations

New York
FUNK AND WAGNALLS COMPANY

[1919]

AUTHOR'S NOTE

In the preparation of this volume I have been assisted by many friends. I am especially indebted to the courtesy of Mr. W. M. Letts, C.B.E., the presiding genius of the destinies of Crossley Motors, Limited, for permission to visit and roam over the magnificent National Aircraft Factory which he built and equipped at Heaton Chapel, Stockport, to meet the national demand for aeroplanes, and to his technical staff in regard to the extension of information concerning the construction and equipment of the aeroplane. My thanks are also due to Messrs. Short Brothers, Limited, for facilities to visit the naval airship works at Cardington, Bedford, and to Mr. E. H. Mitchell, the General Manager of the establishment, particularly in connection with the construction of vessels for trans-oceanic service. I am similarly under an obligation to Messrs. Iliffe and Coatalen for permission to wander over their works to follow the construction of aircraft engines through their many stages, and also to the Handley Page Aeroplane Company, the operations of which I was enabled to study at close quarters. I have likewise received every courtesy and all desired information from the British and Colonial Aeroplane Company, Limited, of Bristol; Messrs. Vickers, Limited; The Rolls-Royce Company, Limited; and many other

friends and firms for data and photographs concerning their activities; also to The Thornton-Pickard Manufacturing Company, Limited, of Altrincham, and to Messrs. Aldis Brothers, Limited, of Birmingham, in connection with their fascinating efforts to render aerial photography so perfect as it is to-day.

CONTENTS

LIST OF PLATES

List of Plates

ALL ABOUT AIRCRAFT OF TO-DAY

CHAPTER I

The Dawn of Commercial Aviation

THE year 1919 stands out as one of the milestones in the eternal march of progress. It recorded the definite introduction of the movement of passengers and freight under commercial conditions by way of the air. A dream, spread over centuries, was at last fulfilled. Ambitious, restless man, after grappling with stupendous problems and wrestling with tremendous issues of a severely technical character, succeeded in turning the atmosphere into a highway for travel.

Yet, if we reflect, we cannot fail to acknowledge that progress in this field, except during the closing stages of the Great Adventure, has been slow. Eliminating the wildly fantastic and the grotesque, as well as the ingenious ideas of the mediæval experimenters, whose efforts were foredoomed to failure from the complete absence of all suitable means wherewith to propel their conceptions through the air, advance has been tedious and precarious; that is, in comparison with relative achievements in the other realms of transportation—rail, sea, and road—each of which was considered equally impracticable and wildly sensational in its day.

All About Aircraft of To-Day

In 1813 "Puffing Billy" was working promisingly at a colliery in the north of England. Eight years later the possibilities of the steam locomotive had secured such a grip upon popular imagination as to lead to the construction of the first iron road essentially for the new means of movement —the Stockton and Darlington Railway, which was opened for traffic in 1825. Within the brief span of seventeen years the locomotive not only had established its commercial potentialities, but was being brought into increasing use far and wide upon an elaborate scale. As with the railway so with the steamship. In 1802 the possibility of driving vessels through the water by steam was conclusively demonstrated with the *Charlotte Dundas;* but Bell clinched the matter beyond all refutation in 1812 with his *Comet.* It was not many years before steamships were plying, not only upon the coastal waters of Britain and North America, but were essaying to plough the deeper and more tempestuous open oceans. The development of motor traffic was equally rapid, if considered in the high-speed internal combustion-engine aspect. The years 1883-4 witnessed the perfection of the first vehicle. The Paris-Rouen race was run in 1894, and in 1896 antiquated legislation, which had retarded expansion and development in these islands, was repealed. From that date advance was spectacularly rapid in every field of application.

Flying has progressed at a much slower pace. It was nearly thirty years ago that the trail through the air was blazed by the French engineer Ader. His achievement, somewhat limited, it is true, imparted a new zest to experiment and endeavour, because success appeared to be within arm's length; but it was not so. Matters drifted somewhat until 1903, when quite a new outlook was presented by the Wright Brothers, in an aeroplane of their own design and

construction, fitted with a motor which likewise was their own creation, flying 260 metres in 59 seconds on December 17, at Dayton, U.S.A. The American achievement, however, failed to arouse the widespread interest which it deserved and which might have been expected. It was received with incredulity mainly for the reason that the reports appeared to be ambiguous, if not utterly lacking in convincing detail; but this was due to the reticence of the inventors, who, naturally, were not prepared to be communicative as to how dynamic flight could be accomplished, until they had secured the utmost protection which the law can extend to the fruit of brains.

Meanwhile experiment was in full swing in Europe, the manifestation of enterprise in this field having preceded the receipt of the intelligence from American sources concerning the work of the Wright Brothers. The Old World investigators frankly declined to believe all that trickled across the Atlantic, and so continued to pursue their way unconcerned, although the mystery surrounding the work in progress at Dayton unwittingly acted as a powerful stimulant to greater effort. It was Santos Dumont and his intrepidity, first with his small airships and subsequently with diminutive aeroplanes, which appealed to the human emotion and riveted the eyes of Europe upon his endeavours, which culminated in the flight of 230 yards in 21.2 seconds at Bagatelle, France, on November 12, 1906. The brothers Farman were also in the field striving for recognition, and it was they who really brought home for the first time in a vivid manner the part which the air was destined to serve as a highway for traffic with their flight of 1,093 yards, during which they notched a speed of 34 miles an hour, on January 13, 1908.

Progress now was somewhat accelerated. On July 25,

1909, Blériot flew the Channel, thereby bringing home to the British public the disconcerting fact that we were not so effectively isolated from the European mainland as we had been for centuries past. We might control the seas and hold potential aggressive continental navies at bay, but the way of the air opened up quite a new situation. To maintain the splendid protection which heretofore our insular position had extended we would need to acquire the dominion of the air as well. So much was perfectly obvious; but, as subsequent events amply proved, we failed to realise the true significance of this menace. Strenuous efforts were made to rouse us from our apathy, but in vain; we refused to be stampeded into action even though it were to make our security doubly secure.

As a matter of fact, aviation in Britain was regarded with indifference. The ventures of the air were regarded as comparable with the daring feats of the acrobat and the wire-walker in the peripatetic circus. The idea of establishing an industry comparable with that associated with the motor-car was received with an utter lack of enthusiasm, while the opportunity to dispute the domain of the air with the bird did not fire our sporting instincts. A powerful effort was made to inflame the British imagination. Lord Northcliffe, with characteristic foresight, realised the peril of our national lethargy, and set out to overcome the danger by extending practical encouragement to British effort. Through the *Daily Mail* tempting prizes were offered for what appeared, in those days, to be wildly impossible feats, doubtless in the feeling that when the Britisher is confronted with the ostensibly unattainable he at once sets out to secure it. At all events it proved to be so in this case because the prizes to be won made irresistible appeal to the British sporting instinct,

although we had already lagged so far behind our Continental rivals as to be considered out of the running.

Appreciating the real value of keen friendly rivalry the prizes were not reserved to British airmen. Other nations were quite at liberty to compete, and they did so to very material advantage, which only served to throw our own backwardness into still more striking relief, and, at the same time, acted as a more powerful spur to the spirit of determination to excel. Of five prizes aggregating £31,100 offered by the *Daily Mail,* four, totalling £21,100 in value, fell to French victors. Henry Farman set the pace by carrying off the first prize of £100 for a half-mile circular flight, on January 13, 1908, at the same time securing the Deutsch-Archdeacon prize of £2,000. Blériot, with his three-cylindered 22-28h.p. engined monoplane, captured the £1,000 offered for spanning the Channel by dynamic flight on July 25, 1909. Louis Paulhan secured the £10,000 London-to-Manchester prize by covering the 183 miles separating the two cities in 252 minutes with one intermediate stop, April 27-28, 1910, while it was Lieutenant "Beaumont" (Conneau) who bore off in triumph, in July, 1911, the £10,000 extended for the aerial circuit of Great Britain. Truly the French airmen may be said to have "scooped the pool," only one insignificant prize of £100 falling to a British competitor, J. T. C. Moore-Brabazon, for his circular flight with a British machine in October, 1909, although this was a contest from which Continental rivals were virtually barred.

During the critical period of development—1907-1912—Britain may be said to have cut a very sorry figure, not only in the creation of airmen, but in the design and fabrication of machines wherewith they might fly. If, however, the British failed lamentably to hold their own in the air during

the experimental days they more than atoned for their remissness by carrying off the greatest prize of all—the £10,000 offered by the *Daily Mail* for flying the Atlantic which was triumphantly, even sensationally, won by Captain Sir John Alcock, D.S.C., and Lieutenant Sir Arthur Whitten Brown, on June 14-15, 1919, by the flight over the span of 1,880 miles of salt water separating St. John's, Newfoundland, from Clifden, Ireland, in 15 hours 57 minutes.

When one recalls the unrivalled inventive record of the nation, the British attitude of indifference towards the way of the air during the accepted experimental era may seem to be remarkable. But what may appear to be still more amazing is that that spirit of apathy still prevails, and to a startling degree. Even the transatlantic flight failed to arouse more than passing interest. It was accepted as an achievement in accordance with British traditions—that the British can do anything when they feel so minded or when circumstances compel. The contemporary general interest assumed towards flying is comparable with that manifested towards other sensational performances, while even interest of an intimate character may be likened to that produced by the first actual experience of shooting the chutes, or looping the loop side-shows, at popular exhibitions.

This inability to grasp the full significance of dynamic flight, and the display of peculiarly narrow interest are readily explicable. The outbreak of war naturally relegated the commercial aspect of flying to the background. The national interests were far more vital, and so everything was subjugated to their complete satisfaction. During the five years of hostilities the nation was thrilled with the amazing feats and often incredible exploits of its fighting-men of the air. They were astonished at the growth of the Third Arm.

Also, the terrific European conflict stirred British productive effort as no other force could have done, and in 1919 Britain reached a position as far in advance of her rivals as she lagged behind them in 1914.

The subordination of all other interests to those of a military and naval character during five weary years created a totally false atmosphere. For sixty months the development of the aeroplane was pursued to one purpose—the scattering of death and the wreaking of destruction. Consequently the man-in-the-street, the woman-at-home and the boy-at-school came to regard the flying machine merely as an instrument of frightfulness. In many quarters it is held out to possess no more commercial possibilities than the submarine. The latter can be converted into a commercial craft and one whereby many of the disadvantages incidental to ordinary sea travel may be avoided in precisely the same way as aerial travel overcomes many of the defects associated with normal movement upon the railway, highway and marine lanes.

Efforts to remove this impression are being made by individual flights, but even these in certain circumstances savour too much of the sensational to be impressive, while in others they are consummated, not from the true commercial point of view, but rather as a subtle form of advertisement. So ingrained is the feeling that the flying machine is essentially a weapon of war that the mass of the peoples of the world, especially those who were compelled to live, move, and have their being in what might be called the fighting arena, resolutely declines to believe that it can ever be turned to commercial account. To the average lay mind it appears about as feasible to convert a fighting aeroplane into a vehicle of commerce as to transform an 18-inch gun into a motor-car,

or a death-and-destruction-dealing mine into a talking machine. It has not yet grasped the commercial possibilities of flying; it does not realise that in the aeroplane we have a force capable of shrinking the world, time, and distance into insignificantly brief factors. It has not yet awakened to the fact that here is a new rival, which is destined to make a bold bid for certain of the traffic at present borne by our express trains, greyhounds of the ocean, and speedy motor carriers of the road.

With the airship it is different. We were forced to realise the possibilities of the dirigible long before the clash of arms re-echoed round the world. From that momentous afternoon of August 9, 1884, when Captains Krebs and Renard, by their completion of an aerial circuit, established the fact that an airship could be manœuvred in the air independently of the forces of Nature as easily as a vessel can be controlled upon the bosom of the ocean, the airship became accepted as an accomplished factor. Count von Zeppelin, despite the derision which his repeated disasters provoked, clinched the matter. So far as the superiority of the dirigible is concerned its success has undoubtedly been the direct result of psychological forces. We pooh-poohed the likelihood of such monstrous craft ever being able to venture very far, but when they brought the war to our doors during the early years of the war, they completely removed all lingering doubts upon this score. In war they proved far more destructive, both materially and morally, than the aeroplane. A striking revulsion of feeling set in. The airship which had been ridiculed became accepted as the future vessel of the air. Its complete safety in the modern form, its enormous radius of action, its flexibility, its capacity to float, owing to the possession of inherent buoyancy, its superior manœuvring

powers, its comfort and its ability to move relatively big cargoes—all these factors serve to invest the airship with superiority over the aeroplane in the minds of the average individual.

To bring home the possibilities of the aeroplane is certain to prove a tedious task. A ceaseless and aggressive campaign of enlightenment and education will be imperative, and many years must necessarily be occupied in this uphill task. The achievements of war count for little or nothing in the eyes of the people who must be won over to assure commercial success for the new force which is destined to effect such a complete transformation of our complex social and industrial life. We know that enormous strides were made during the war in the perfection of the aeroplane. We appreciate, even if only faintly, that under the stress of five years' incessant battling for superiority over a stubborn well-equipped enemy, raised and trained for war, as much progress was achieved by Britain in the domain of dynamic flight as would have been recorded during a quarter of a century's normal development. Even the most unsophisticated among us know equally well that military and naval exigencies compelled the incurrence of risks which would never have been tolerated for one moment under peace conditions. What did it matter if a machine, costing thousands of pounds, crashed upon its first flight to become resolved into a tangled heap of torn linen, broken wires, splintered wood and shattered engine? The country paid the bill. Of what significance was it that a brave man lost his life in trying out a new idea? It was dismissed as an incident inseparable from war. But consider the situation from the commercial point of view. A crashed machine represents a material loss to the owner or underwriter. Those who are exposed to the risk of being

called upon to reimburse the damage wrought exercise a restraining influence, while, if insurance is ignored, then the company associated with the enterprise, if crashes are many, must be prepared to enjoy but a fleeting existence. Again, under peace conditions, a higher value is set upon human life, and recurrence of fatalities is certain to provoke as fierce and widespread an outbreak of public feeling against the aeroplane as did the death-roll incidental to motor-racing bring about the abandonment of this form of sport.

What has war contributed to the new science? What is the position to-day? What influence will the lessons of the battlefield and the seas exercise upon future developments? If the answer must be unequivocal, war has not exercised any decisive influence in so far as the actual science of aeronautics is concerned. The flying machine of 1919 is what it was in 1914—a mechanically propelled kite. No sensational revolutions in regard to design have been recorded, while in one or two directions war has really hindered progress.

The fields in which important benefits have been bestowed, however, are many and of far-reaching significance. The aeroplane was taken over to become regarded as an instrument of national importance. Individual effort for the most part became submerged. The country had first call upon the most brilliant brains and most accomplished manufacturing skill. From John o'Groats to Land's End extended one vast national aeroplane manufactory. A laboratory such as private enterprise could never have created became established, and there were unlimited funds in the bank of the National Treasury to furnish the sinews with which progress alone can be recorded. It was immaterial how much an experiment would be likely to cost. It was pursued. Ideas

might crowd upon one another in an amazing manner, but that did not preclude them being submitted to the test. Anything and everything which was desired was forthcoming; expense was no object. The nation was not in the position of a private company, which is necessarily compelled to study the claims of those who finance operations—the shareholders. We were all shareholders in the National Aeronautical Laboratory and Factory, and expected no return beyond maintenance of our homes and shores.

In this manner it became possible to control inventive ability. There was no competition. The product of brains became classified and diverted into well-defined channels, to be pursued to its logical conclusion. The galaxy of talent, by skilful selection, achieved many startling wonders. It contributed to the defining of constitutional scientific laws and their due observance; the freakish was ruled out. It led to standardisation and the evolution of the most perfect designs. We learned much concerning materials; the precise adaptability of this wood and that metal for specific purposes. The primitive was forced to one side to make way for the ultra-modern and mechanical. Every conceivable branch of the craft was covered, and the maximum amount of brains possible for each ramification was secured and turned to account. Behind it all was exercised a driving force or pressure which could not be subjugated. The policy, "We must have it; never mind the cost" alone prevailed.

What is the position of affairs to-day? The lever of national incentive has been withdrawn; it has accomplished its work. The companies swept into the vast net have been released. They have reverted to the positions they occupied in 1914, or, if born since then, have been freed to pursue their ways untrammelled. Each now stands upon its own

footing. There is no inexhaustible barrel in which to dip for the requisite finance. The shareholders once again become the dominant factor. The national laboratory has been dissolved. Each firm must now establish its own thinking department and evolve its own ideas. In these circumstances the pace has slowed down, and for the next decade progress promises to be exceedingly slow, unless something revolutionary is produced by science to change the whole aspect of things. Competition is restored not only between the various manufacturing firms, but with the other and accepted channels of movement and communication. To-day, in the conduct of any commercial transaction, the question arises, "Shall I use the aeroplane, the steamboat, the railway, the motor-car, the telephone, the telegraph, or wireless?" In other words the way of the air is relegated to a well-defined niche, and is brought into conflict with coldly-calculating, unemotional commerce.

Under the incentive offered by national necessity we have been able to attain overwhelming world-wide supremacy. The British aeroplane is conceded to be a masterpiece of design and construction. The rigid standardisation of materials has made it possible to present machines which, for strength, cannot be excelled. Then in regard to engines enormous strides have been made, and the development of the power for the mechanical unit is truly startling. Ten years ago the machine with which Blériot flew the Channel developed only 22-28 h.p.; now we are equipping machines with monsters as beautifully designed and built as a chronometer of 350 h.p., while contemporary airships are being fitted with giants developing 900 h.p. Speeds have risen amazingly during the decade, the two extremes being the 45 miles an hour notched by Blériot as compared with

velocities ranging up to 150 miles an hour which have recently been recorded.

With improved aeroplanes having more reliable engines the radius of action has increased rapidly. Places which six years ago appeared to be wellnigh inaccessible from London by air in a quick flight, or the realisation of which constituted a remote dream, are now regarded as common-place achievements. It is doubtful whether such big efforts to determine the endurance of the machine and of the man at the helm would have been made under peace conditions. War applied the spur. Lieutenant Marchal set the pace in this direction by establishing a record of 811 miles in June, 1916, with his flight from France to the Russian frontier, viâ Berlin. This was topped fourteen months later by the aerial run made by Captain Marquess Guilio Laureati from Turin to Naples without any descent, a distance of nearly 920 miles. The following month, September, 1917, this intrepid aviator accomplished another striking performance with his cross-continental flight of 3,656 miles from Turin to London.

Flights such as these demand the provision of supplementary fuel tanks, involving departures from standard design, or, at all events, normal commercial practice. Consequently, the next step was the achievement of comparable long journeys in easy stages, the intermediate descents being made to secure further supplies of petrol, and without making attempts to establish time records. In this direction must be mentioned Commander Savory's flight over the 2,000 miles separating London from Constantinople in December, 1917, and the more leisurely run from England to India by Major Maclaren, and that of Lieutenant-Colonel W. D. Beatty from London to Madrid on May 12, 1919.

It was the subjugation of the Atlantic by air which

revived the public enthusiasm in the aeroplane, although, at the same time, it brought home very convincingly the fact that we have a very long row to hoe, and that considerable time must yet elapse before the aerial highway can be regarded as being able to sustain traffic with that clock-like regularity identified with our railways, streets, and ocean lanes. It effectively nonplussed those who were so strenuously advocating the immediate establishment of long-distance aerial routes, and who talked lightly of circumflying the earth in a week. Hawker's unfortunate fall into the Atlantic after covering 1,000 miles, and the failure of two out of three competitive American flying-men to make the Azores, brought home the susceptibility of the power unit to failure; that it had not yet been advanced to a sufficient degree of reliability to enable it to carry the plane anywhere, at any time, and under all and varying conditions. The feat of Commander Read, of the United States Navy, who, leaving Trepassey Bay, Newfoundland, on May 16, 1919, making the Azores 1,381 miles, Lisbon 1,094 miles and Plymouth 895 miles—a total mileage of 3,370—but who did not reach his destination until May 31, testified very clearly that the aeroplane was not to be considered as a serious rival to the established systems of transit. The Alcock-Brown flight of 1,880 miles in 15 hours 57 minutes created the greatest measure of excitement, but not so much from the circumstance that the Atlantic was spanned in one big aerial leap, as from the high average speed attained—117½ miles an hour—and the wonderful endurance of the men in charge of the machine.

The uncertainty revealed by the Atlantic flight has really proved a blessing in disguise. Had the aviators jumped into their machines immediately they had been assembled, and

made the flight without incident, a totally false atmosphere of reliability and regularity would have been associated with the aeroplane. Commerce might possibly have accepted the aerial transatlantic highway as being definitely opened. In that event, if any subsequent fiasco or hiatus had eventuated, commerce would have turned her back upon aerial transit, and superhuman effort would have been required to induce her to regard the movement ever again with favour. Blériot flew the Channel in 1909, but the mails, freight and passengers still go by the usual routes to and from the Continent.

The development of railways and steamships, concerning the certainty of regular movement upon which there can be no dispute, has always been guided by one golden principle, "Make haste slowly." Commerce will not be stampeded into action, is difficult to woo, and when won must be held at all costs. As with the steelway and the sea so with the air. Once an aerial highway is opened it must be maintained at all hazards and irrespective of expense. Fortunately, the pioneers of contemporary aerial navigation recognise this circumstance only too well. So they too have adopted *Festina lente* as their motto. They frankly admit that years must necessarily pass before the way of the air becomes firmly established in popular favour, and readily concede that there is yet much to learn before any definite action can be taken in this direction. They are disposed to advance by easy stages, admit frankly that breakdowns and galling delays are likely to occur, but aver that each difficulty will extend its lesson and lead to the adoption of means whereby its repetition may be averted. Thousands of pounds will doubtless be lost in the process of evolution, many organisations established to open the way of the air will come to grief, a wave of speculation will be experienced, and serious harm

will attend precipitate action. It may even be necessary to forget a good deal of what we have learned from the war, military conditions being so completely inapplicable to commercial needs, and to resume quite methodical and well ordered development from the stage where it was summarily interrupted in 1914. Success will only be achieved upon the ruins of the fabric raised by the pioneers.

To illustrate that the war was not omniscient in matters pertaining to aviation we need only to consider the situation as it affects the monoplane. In 1914 this type was generally accepted as being the most promising. Certainly many of the most brilliant achievements in aviation stood to its credit. But superior military knowledge overruled its claims and made many objections to its further development. Subsequent events tend to prove that this attitude was assumed from the angle of prejudice. The anti-monoplanists secured the upper hand, but we learned in good time the error of their ways. The Germans designed a fast, and, so it is conceded by those who were brought face to face with it, a first-class monoplane, that is judging from the speed and general behaviour point of view. With this unit they harried our slower-going aircraft over the North Sea. It was a bold bid to gain the upper hand in the air, and it led us to reconsider our position, the upshot of which was revived concern in the possibilities of the monoplane. The French were particularly prompt to revise their opinion of the monoplane and had completed arrangements for its development upon a wider and more intensive scale, which undoubtedly would have been carried into effect but for the intervention of the Armistice.

For certain ranges of commercial work the monoplane undoubtedly is unrivalled, especially in these islands. The

probability is that commercial flying will make but little headway in Great Britain. Geographical situation and the excellence of rival means of transit and communication will react against its widespread use for at least heavy and mail traffic. In other countries, however, such as the Continent of Europe, Africa, Asia, Australia and North and South America, there are incalculable possibilities for its expansion in every phase. At the same time the aeroplane is likely to be extensively developed in the British Isles purely for recreation or joy-riding as well as light commercial work. To the "hustler," whose daily itinerary is lunch in Manchester, an afternoon cup of tea in Edinburgh, dinner in London with a run over to Paris to the opera in the evening and the week-end in New York, everything will have to be subservient to speed. The monoplane, by virtue of its enormous pace, will appeal to him as a commercial and sporting aerial vehicle. On the other hand, for every individual who wants to scurry round this globe as if bent upon out-distancing his shadow there are a hundred who prefer to travel leisurely, in luxury and comfort, and they will adhere to the existing means of movement. To them the air will make no appeal except as an intermittent novelty, and even then moderate pace will appeal.

Another apparent retrograde movement is to be recorded in connection with reversion to the single-engined aeroplane. The war was productive of magnificent types of twin-engined craft, but certain of our technicians have expressed dissatisfaction with the type. Now they are free to "gang their own gait" once more they have decided to rest content with the single-engine unit for the time being, and to pace slowly the path of mergence into the twin-engined aeroplane. It looks like putting the clock back with a vengeance, but they are

merely acting in accordance with the dictates of prudence, animated by the experience of a specialised nature which they have collated.

From circumstances such as these it is evident that it is expedient to forget much that the war has taught. Individual private enterprise, stimulated by competition, has ever been productive of more genuine and permanent progress than communal effort under nationalised conditions. Communal activity is apt to become rutted; the progress recorded under such conditions is somewhat artificial because it is forced and confined. Free development is likely to bring about the elimination of many of the little troubles and worries which at the moment are really handicapping the establishment of aerial navigation upon a sound commercial basis. Moreover, it is likely to lead the technical mind into by-ways and *culs-de-sac* where much data of incalculable value may be discovered as a result of methodical investigation; but data which may be overlooked when endeavour is driven under pressure down a wide well-defined path. It is such individual effort which is likely to lead to the discovery of quite a new method of driving the aeroplanes through the air, or the evolution of a power unit of a distinctly improved type. The modern aero-engine, while a marvel of workmanship, bristles with defects. They are innate to the system. The aeroplane at the moment suffers from its incapacity to rise and descend vertically, or to hover. Until these two characteristics are incorporated—they are a feature of the dirigible lighter-than-air machine—the way of the air by the aeroplane is destined to remain an uncertain problem and incapable of fulfilling the whole of the requirements of commerce.

Thus it will be realised that although much has been accomplished, finality in design is as remote now as it was

in 1914. There are still golden opportunities for brilliant inventive genius. Meanwhile, in order that the movement may not be arrested, it is necessary for us to push ahead with what we have. Therewith we can blaze the aerial trails of the earth, and thus be in readiness for a big forward boost the moment something revolutionary, and representing a distinctly forward stride of a far-reaching order, materialises.

CHAPTER II

Why We are Able to Fly

BARELY ten years ago the conquest of the air by dynamic flight constituted the sensation of the hour. Crowds, flushed with excitement, flocked to the aerodromes to follow the evolutions of the birdmen. The sight of cumbrous, albeit frail-looking creations of wood, linen, and slender wire, climbing into the air and travelling a few miles in a straight line or broad sweeping circles, kindled extraordinary enthusiasm. No longer was the bird the autocrat of the realm over which he had held undisputed sway since the day when this world of ours was first able to support life.

What a change has been wrought by a decade of progress! We no longer marvel at the amazing feats executed in the air. The most astonishing achievements are accepted as being merely matter-of-course. War, with its strenuous aerial training, has divested flying of its romance; has even bred a spirit of indifference. The intelligence that an intrepid aviator has climbed to a height of 30,000 feet, or has sped through space at 200 miles an hour scarcely causes a flicker of the eyebrows. Even the subjugation of the broad, tempestuous Atlantic by the heavier-than-air machine fails to arouse more than fleeting interest. 'Twas ever thus. The ultra-wonderful of to-day becomes common-place to-morrow. Such is the penalty of progress.

At this moment we do not marvel at man being able to

fly. Fortified with the knowledge we have gained, we are disposed to wonder why it was that man did not achieve his triumph many years ago. It is so simple—so delightfully easy. So says the airman, and, to a pronounced degree, he has been responsible for the quaint, disinterested spirit which now prevails.

Yet, why is it we are able to fly? Certainly Mother Nature has not endowed us with this capacity. But ambitious man did not construe the absence of wings, which gives the bird command of the air, into an insuperable obstacle. By dint of his ingenuity he has been able to remedy the remissness of Nature very effectively. True, for a time, he floundered hopelessly in the dark. He endeavoured to follow Nature too slavishly in the attempt to consummate his end. He contrived weird artificial wings, sometimes going even to the extent of feathers, and sought to fly, by emulating the bird, with a flapping motion; and, as is invariably the case when seeking to reproduce Nature too closely, he encountered dismal failure. The most perfect bird's wing might be contrived and it might be given the most beautiful flapping motion, but it would be foredoomed to failure for the simple reason that it would suffer from an utter lack of sensibility. It would be of no more actual utility than an artificial limb. It would need to be connected to that wonderful and intricate network which we know as the nervous system of the human body; to be linked with the brain so as to be invested with instinctive movement, not only of the whole, but of integral parts, even to a single feather.

It was really the general belief that artificial wings would have to follow the form of those of the bird which postponed the realisation of dynamic flight for so many centuries. Even so recently as the closing decade of the nineteenth century

this theory prevailed, because Lilienthal and his contemporaries still clung to the bird's wing as the solution to the problem. It was this blind adherence to a fallacious reasoning which retarded progress, although it is generally conceded that the experiments of these pioneers did contribute to our knowledge of aerodynamics, but this was rather in relation to the atmosphere itself than to the lines which the planes should assume.

Had the pioneers been more generous in their theories they would have attained greater success. The fundamental principle upon which the modern aeroplane is based is not so recent as might possibly be imagined. It has been known for hundreds of years, while it constitutes the companion of every boy. I refer to the kite. This recreative apparatus follows a variety of designs, for the simple reason that the kite itself has been the object of sustained scientific interest and investigation through the passage of time. Although nominally regarded as a toy, it is capable of fulfilling far more serious missions. By its aid many problems of an extremely abstruse character have been, and still are being, probed, while its utilisation has contributed very materially to our knowledge of meteorology and the upper atmosphere. The relationship between the kite and the aeroplane may seem to be obscure, but after all is said and done the heavier-than-air flying machine, as we know it to-day, is no more or less than a mechanically-driven kite, or, as Captain Ferber, one of the indefatigable pioneers so aptly expressed it in another way, "the kite is only an anchored aeroplane."

Why does a kite fly? This is an obvious question. Without dipping deeply into the profound and obscure science of aerodynamics, the reason for its soaring tendency may be readily explained. Briefly stated, it may be said that the kite

flies because means have been found to control and to harness the resistance of the air. A kite in flight is subject to the influence of four forces, the cumulative effect of which ensures its soaring tendency. These are respectively the downward pull of the earth, or gravity, which is due to its weight; the upward thrust of the air; resistance of the air; and driving or propelling effort. The two first-named act in the vertical direction; the two last-named in the horizontal plane.

In order to fly the kite, the latter must be inclined, and the more accentuated the inclination towards the horizontal, up to a certain and pre-determined point, the more enhanced the soaring tendency, because the lifting effort is directly proportional to the degree of inclination and the attendant resistance offered to the air. Obviously, the nearer the approach of the kite to the vertical position the greater the area exposed to the resistance of the air, and consequently the weaker the upward vertical thrust. The latter is always at right angles to the degree of inclination, and the kite, in its ascent, follows that line so long as no pull is exerted upon the string, the latter being paid out freely. That is why a kite always rises, as it were, up an inclined plane. Thus it will be seen that the upward vertical thrust is directly attributable to the air resistance. As the inclination of the kite approaches the vertical, the upward thrust approaches the horizontal and so diminishes; obversely, as the inclination of the kite approaches the horizontal, the upward thrust moves towards the vertical and thus increases, as explained in Fig. 2.

This may be proved very readily. If we fly a kite in a very light wind, a zephyr, for instance, from a fixed position, the angle assumed by the kite will be pronouncedly towards the vertical. The kite does not rise very promptly or markedly, although a long length of string may be paid out,

the kite being relatively free. Owing to the area of resistance exposed to the wind being large the kite is driven backwards, slowly climbing meanwhile owing to the upward thrust due to the resistance of the air, as shown in the diagram. It may so happen that the kite will reach the vertical position, in which event it will promptly make one of those disconcerting dives, for the simple reason that the weight of the kite having overcome the upward thrust, pulls it to the ground.

On the other hand, if a strong wind be blowing, the climbing effort of the kite will become very pronounced. It will climb and climb until it attains a position almost directly overhead, although, in this instance, possibly less string has been paid out. But the greater altitude attained is due to the fact that, owing to the increased pressure of the wind, the kite has been induced to assume a more inclined position relative to the horizontal due to the stronger pull on the string.

It must be understood that the pull on the string really acts in the same way as the motor fitted to the aeroplane. When the string is taut it is as if a tractor propeller were pulling the kite forward. This fact is proved in the instance with the kite flying in a light wind. Directly we begin to pull in the string, thus tightening it, the kite commences to rise, for the simple reason that the pull, otherwise the motor effort, causes the kite to assume a sharper angle towards the horizontal, decreases its resistance to the air, and at the same time increases the upward thrust. In the second instance the effect of the combined influence of these two forces is far more strikingly in evidence, much more effort being required to haul in the kite. All those who have flown a kite know full well how much more arduous it is to bring in a kite during a stiff wind than when there is only a gentle breeze prevailing.

Of course, the actual upward thrust which induces the

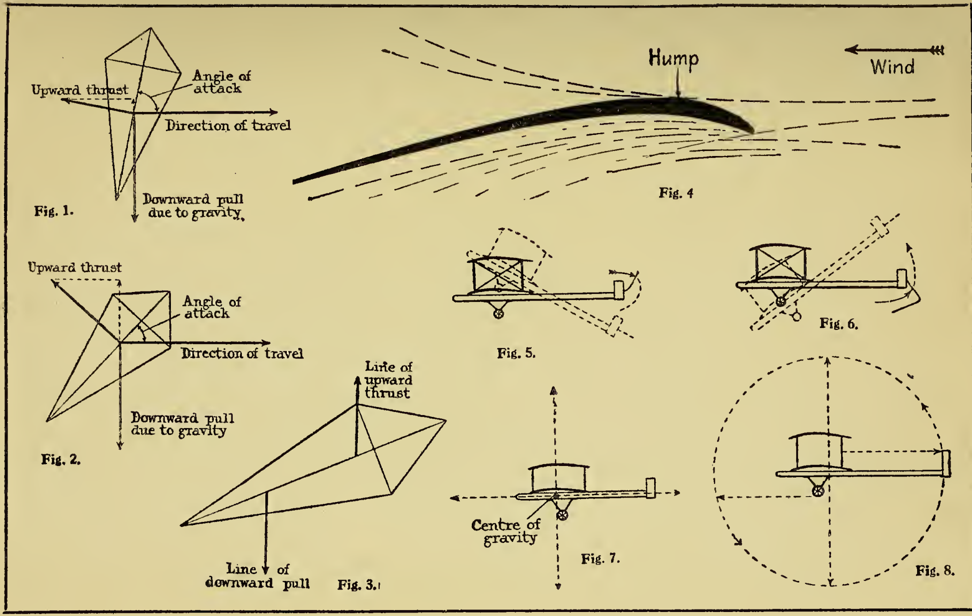
kite to rise, is exerted in a vertical direction, and not at right angles to the inclination of the kite, because this effort is in the diametrically opposite direction to that exercised by gravity, which is in a truly downward vertical direction. If the kite be properly balanced, these two forces will be expended in opposite directions and along one continuous line; but to do this it is essential that the line in question should pass through the centre of gravity of the kite. Should there be any error in this connection—the line representing the vertical upward thrust being exerted from one point, as shown in Fig. 3, and the downward pull due to gravity from another—the kite becomes unstable, and, accordingly, will perform those extraordinary gyrations sometimes observed, which the flier rectifies by adjusting the tail either by making it longer or shorter. If the tail be too long, the centre of gravity will tend toward the lower end of the kite, while, on the other hand, if the tail be too short it will approach the upper end. But in either case the ultimate result is the same. The kite is not in equilibrium in regard to these two forces, and will gyrate, owing to the struggle which naturally ensues between these two forces to come into line.

But stability in the vertical direction is merely one phase of the issue. There must be similar equilibrium in the horizontal plane. If the string be wrongly placed, such as too high or too low above the line of air resistance, the kite will gyrate, notwithstanding the upward lift and downward gravitational pull being in line. Consequently, we generally have to make a good many adjustments before our kite flies in a well-ordered manner, successively shortening and lengthening the tail and moving the string. Final success in the main is due to trial and error, the deficiences being rectified one by one as discovered.

The truly-balanced or stable kite is that in which the lines of the opposing forces meet or intersect at the centre of gravity. When this degree of perfection has been achieved, the kite will be found to be in absolute equilibrium, and will soar in the most perfect manner. It is immaterial what design of kite be employed, whether it be the familiar, semicircular topped and sharply pointed, plane surface, the box kite, or the grotesque and wonderful creations which have been associated for so many centuries with the Chinese—who, by the way, are the most accomplished and most scientifically skilled kite-fliers in the world, some of the kites being sixty feet or more in length, and, when aloft, representing a fantastic dragon or some other allegorical creature in flight.

The fundamental principles governing the kite must be observed in the aeroplane, although there are many modifications in detail to adapt this device to the conditions. Thus, the planes or wings are so disposed as to present an inclined plane to the air when the body or fuselage is truly horizontal. The normal angle varies, but it is about eight degrees. Moreover, the plane is given a humped shape in section, the hump being brought forward near the cutting or front edge of the wing. In this manner the wing is given a concave surface, the concavity being towards the earth. It was introduced originally because it was found to conform with Nature's design as exemplified in the bird's wing, while subsequent technical investigation and computation confirmed the superiority of this shape. Consequently, if one were to cut a slice from the end of a wing of the modern aeroplane, one would find its outline to coincide roughly with that shown in the diagram Fig. 4.

The similarity between the kite and the aeroplane in regard to fundamental principle of operation may be carried


Upward thrust
Angle of attack
Direction of travel
Downward pull due to gravity.
Fig. 1.
Hump
Wind
Fig. 4
Upward thrust
Angle of attack
Direction of travel
Downward pull due to gravity
Fig. 2.
Line of upward thrust
Line of downward pull
Fig. 3.
Fig. 5.
Fig. 6.
Centre of gravity
Fig. 7.
Fig. 8.

farther. The prevailing practice is to set the propeller in front of the machine. By its revolution the propeller draws the aeroplane through the air in precisely the same way as the pull of the string upon the kite causes the latter to rise. This may be more convincingly illustrated by running with the kite in flight. The reason why the kite exerts a more pronounced tendency to rise when the flier runs is because thereby he exerts a more powerful pull upon the string, which, in turn, increases the resistance of the air upon the kite's surface, thus augmenting the upward thrust. It is the same with the aeroplane. The faster the propeller is driven, and the closer the number of revolutions per minute approaches the pre-determined limit, the more enhanced the lifting effort. The propeller cannot be driven at an excessive speed for the simple reason that, having displaced the air, it would be rotating in a partial vacuum, and so would fail to secure that requisite "bite" upon the medium of resistance which it is essential should be encountered to acquire the requisite lifting tendency.

But the kite is anchored. Its altitude, in the main, is governed by the length of string paid out. If the conditions be favourable for holding the string from a fixed point, the kite will continue to rise until the weight of the string itself commences to be felt, although ascent will continue all the time the upward thrust is able to overcome the downward pull of gravity due to the weight of the kite and its string. The aeroplane is a free kite, and so means have to be incorporated to prevent the machine from steadily rising when a level course is desired. This is secured by the introduction of what is called the empennage. This is the unit attached to the rear end of the body of the artificial bird, and acts in the same capacity as the tail of the denizen of the air. The empennage

is a somewhat comprehensive term, inasmuch as it includes the whole of the stern gear comprising the rudder, fixed tail-plane, and the elevator. This last-named really controls the rising tendency of the aeroplane. It is a flap or hinged surface, the edges of which are parallel with the wings of the machine, and it can be moved up or down according as to whether it is desired to descend or to ascend.

If the flap be raised the increased resistance offered to the air above the machine causes a depressing action to be exerted upon the tail, and a corresponding degree of elevation to the nose of the machine, so that the aeroplane is able to climb (Fig. 5). On the other hand, if the elevator be depressed, resistance to the air is offered beneath the machine, and so the tail is forced upwards, causing the nose to be depressed. A downward course is instantly followed (Fig. 6). In the circumstances, therefore, if the elevator be set to the required angle the natural upward thrust imparted to the machine by the increased rotation of the propeller can be nullified and a perfect horizontal course maintained.

I have mentioned that the ideally balanced kite is one in which the opposing forces, both vertically and horizontally, are exerted along continuous lines. The same applies to the aeroplane. Assuming the normal course of the aeroplane to be perfectly horizontal, these two lines should pass through the centre of gravity (Fig. 7). If this be fulfilled, perfect equilibrium will be imparted to the machine. On the other hand, should either be thrown out of alignment the machine becomes unstable and dangerous, because the error is certain to impart a spinning tendency to the aeroplane, as shown in Fig. 8.

But perfect equilibrium is only secured in the one position—namely, when the aeroplane is travelling in the horizontal

direction. The centre of thrust, or pressure—that is, the point where the lifting effort is exerted—is constantly moving. In the actual aeroplane, the centre of pressure is manifested along a line extending from wing-tip to wing-tip, and this line approaches the front or cutting edge of the wing, that is in advance of the centre of gravity, as the inclination of the wings approaches the horizontal, and moves back as the aeroplane's inclination approaches the vertical.

Of course, both these movements may be pushed to an excessive degree. If the nose be depressed below the horizontal, the centre of pressure becomes changed from the under to the upper side of the wings, and the machine immediately commences to fall vertically like a stone, or to glide downwards. On the other hand, if reared too vertically, the machine will be turned over on its back. It is by virtue of these excessive motions under control, coupled with high engine speed, which enables such startling aerial manœuvres, or stunts, as "looping the loop," rolling, spinning, and spiralling, to be conducted in safety.

There is one feature identified with flight which distinguishes it from every other form of locomotion, with the exception of submarine travel. Movement is possible in the three dimensions, whereas in all other forms it is either in the one or two dimensions. In other words, the airman is able to move longitudinally, transversely, and vertically. In walking, a man or animal has command of the two dimensions—length and breadth only. On the other hand, the railway locomotive, or any other system of motion confined to a track, can only move in the one dimension. Birds and fishes have control over movement in the three dimensions for the simple reason that they are wholly immersed in the medium in which they exist. This is why the submarine may be compared

with the flying-machine, because both have command over movement forwards, sideways, and up and down. Consequently, in view of this factor, the aeroplane must be invested with equilibrium, not only longitudinally, but transversely, and must be equipped with the means of maintaining this equilibrium under varying conditions.

Command of the machine in the transverse plane is assured by means of what are known as ailerons. These are hinged flaps, similar in design to those of the elevator, and are let into the outermost rear corners of the wings. Their edges are parallel with the edges of the wings, while the rear edge of the aileron is flush with the rear edge of the support and plane surface. When set normally, they form a continuation and part of the wing. In the case of a biplane the ailerons on each plane are connected; *i.e.* the aileron of the upper wing is coupled to its fellow on the wing beneath, so that the two act in concert and to the same degree. The wires whereby their movement is effected are carried to the control-lever or "joy-stick," and their action is broadly similar to that of the elevator, because they are introduced to fulfil a similar purpose—steering in the lateral plane. But each pair moves in opposition to its fellow. We have all observed how a racing cyclist speeding round a circular track inclines his body towards the centre of the circle which the track describes, while to assure stability we know that the track is banked, so that the machine and rider shall be perpendicular to the surface of the track.

A similar effect takes place in the air. In turning to the left the machine inclines toward the centre of the circle which it is describing. But in describing the turn, we have an effect comparable with that experienced upon the roundabout. The tip of the outer or right wing has to travel farther than

the tip of the inner or left wing. Consequently, stability must be maintained; in other words, greater sustentation must be imparted to the tip of the left or inner wing. If this were not so the machine would either slip sideways along the line of inclination of the machine, or it might possibly turn right over. The ailerons, however, extend just the additional support which is desired, and by their peculiar movement exercise a correcting effort which is sufficient to counteract slipping or capsizing.

In making the turn to the left, the aviator moves his "joy-stick" to the left. In so doing he slightly elevates the ailerons on the extreme tips of the right wings, and at the same time the ailerons on the extreme tips of the left wings are correspondingly depressed. The aileron surfaces on the right wing tips, by projecting upwards, strike the air, and the resistance thus encountered from above tends to force the elevated part of the machine in a downward direction. On the other hand, the aileron surfaces projecting downwards from the extreme tips of the left wings meet the pressure of the air which is being exerted upwards, and which tends to push that wing upwards. This counterbalancing effort is maintained the whole time the machine is turning, and has the effect of restoring the machine to the even keel the moment the course is straightened, when the ailerons are returned to their normal position. In turning to the right, the action and tendency are reversed, the upward thrust of the air bearing upon the inner right wing ailerons which are depressed, and downwards upon the left wing ailerons which are turned upwards.

Longitudinal stability is maintained in a broadly similar manner, because the elevator planes are really ailerons, though acting in the vertical plane. They are likewise connected to the control-lever or "joy-stick." To climb, the

aviator pulls the control-lever backwards, and to descend, pushes it forward, with the effect previously explained.

All the movements of the "joy-stick" are natural. The aviator moves the lever in the direction in which he desires to go—namely, backwards when he wishes to rise, and forward when he wishes to descend. To turn to the left he swings his lever to the left, and *vice versa.* It will be seen that the control of the ailerons and the elevator is carried to one common lever, which is essential, because the movements are interdependent, and both may need to be made simultaneously; as, for instance, when climbing and making a turn at the same time. One single control for the maintenance of stability in the two directions, longitudinally and laterally, is infinitely superior to an individual control for each movement in the two planes, because it can be conducted by one hand and instinctively. This arrangement has necessitated a special form of mounting for the "joy-stick"—upon the ball and socket principle—giving command over a fairly wide circle, and allowing movement in any direction within that circle. In some of the recent machines this simple method has undergone a modification. The control-lever is given movement only in a fore and aft direction for the manipulation of the elevator. A wheel is vertically mounted upon the upper end of this column, as if the wheel upon the pillar of a motor-car were folded over, rotation of which, in the right or left direction, moves the ailerons.

To maintain the course of the machine in the desired line of flight there is a rudder. This is another plane surface or aileron, set vertically and upon the longitudinal axis of the machine. Two wires extend from the rudder to be connected to the extremities of a transverse, centrally-pivoted bar in the pilot's cock-pit. This bar is controlled by the feet,

and has an oscillating motion about its axis. When the right foot is pushed forward, moving the rudder bar in that direction, the stern plane is turned so as to offer increased resistance to the air, which, pressing upon the surface, pushes the tail of the machine round, swinging the nose of the machine round in the opposite direction, *i.e.* to the left. When the left foot is pushed forward upon the rudder bar the machine, of course, wears to the right.

Yet, although the fundamental principles concerning the flight of a kite have long been known, dynamic flight failed to make any progress until a few years ago. Although many brilliant minds attacked the issue, they achieved nothing but failure. Strive how they might they could not replace the string of the kite by an efficient light engine. Considerable effort and ingenuity were expended, but to no avail. In the struggle between weight and power, weight maintained the upper hand. Power might be increased, but the augmentation of weight to secure that power was always disproportionate to the results attained. It was not until this state of affairs could be reversed, power gaining the ascendancy over weight, that progress could be recorded. It was the high-speed internal combustion engine, giving high power for nominal weight, which instantly lifted dynamic flight from the dreamland in which it had been imprisoned for centuries to the world of practical and commercial application. The struggle still prevails, but it is less harassing than it was in the days when steam alone appeared to be the only possible solution of the problem.

During the past few years the progress recorded in regard to the application of power to the aeroplane has been somewhat remarkable, as I have recorded in another chapter, and ingenuity has found expression in many forms. But this

in turn gave rise to other problems. The single unit had been carried to an extreme degree, and possibly is approaching its limit, because power means weight, even to-day, and weight involves increase in the dimensions of the planes or carrying surfaces to preserve the equilibrium of the fundamental forces involved. It is for this reason that we have seen planes growing in size; but there are limits in this direction, under present conditions. The larger the plane the more difficult is its control; so progress in the one direction will necessitate the incorporation of new ideas in the other, which are certain to introduce perplexing factors, the significance of which, as yet, cannot be anticipated.

When one comes to consider the navigation of the lighter-than-air flying machine, vastly different conditions arise, although, so far as the fundamental requirements are concerned, there is very little difference. The airship, like the aeroplane, is subject to the combined force of lift and gravitational pull, operating in opposition in the vertical plane, and to the combined forces of air resistance and propelling effort in the horizontal plane. So far as the two first-named are concerned, the problem is solved, but in a totally different manner. Ascensional or lifting effort is imparted to the vessel by recourse to an agent which is lighter than air, stored in an envelope or bag.

There are several such mediums, such as ammonia-gas, carbon-monoxide, coal-gas, helium, hot-air, hydrogen, and water-gas. Ammonia-gas is out of the question because it readily attacks the fabric which is at present employed to form the envelope. Carbon-monoxide could be employed, but any leakage would spell instant death to any living being in the vicinity, because it is extremely poisonous. Helium would be excellent for the purpose, for the reason

that, while somewhat heavier than hydrogen, it is safe to use; but it suffers under the disability of being expensive, and it has only about one-half the lifting capacity of hydrogen. During the middle of 1919, however, means have been perfected to obtain this gas at a relatively trivial cost. Hot-air is ruled out of commercial application because it cannot be maintained at the requisite temperature during the period of the flight.

Accordingly, the gases available for this purpose become narrowed down to hydrogen, coal-gas, and water-gas. Hydrogen is the well-known element, of a highly inflammable character, which, to-day, can be produced very cheaply. Coal-gas is the familiar product resulting from the distillation of coal, and which is composed essentially of hydrogen and methane gases, but heavily adulterated with various impurities, such as sulphur, which, however, are capable of complete removal.

Water-gas, or as it is more familiarly called, producer-gas, is obtained from the decomposition of steam by passing it over glowing charcoal, the gaseous product thus secured being composed mainly of hydrogen and carbon-monoxide. If produced under high temperature conditions, the proportion of these two gases will aggregate about 90 per cent. of the whole, the balance of 10 per cent. being represented by various other deleterious gases, including carbonic acid gas.

When the Montgolfier Brothers demonstrated the possibility of lifting an inflated spherical, or rather pear-shaped, envelope into the air by the aid of hot-air, brilliant minds at once conceived the idea of imparting dirigibility to the craft. When Green introduced coal-gas as the lifting agent, demonstrating its superiority to hot-air for the purpose, this line of investigation was very pronouncedly

stimulated. But these pioneers speedily discovered the impracticability of achieving their end. They found it absolutely impossible to endow the vessel with the qualities of dirigibility; they only encountered threatened disaster as the reward for their pains and ingenuity. The moment they extended a device, such as a sail or plane, to endeavour to deflect the balloon from its course, which was the direction in which the wind was blowing, the vessel commenced to heel over in the direction of its line of flight.

The reason for this action is perfectly obvious. It is impossible to secure dirigibility unless the vessel be invested with a speed of its own, or independent speed, as it is called. A rowing-boat will prove this fact very convincingly. If the boat is merely being carried along by the tide or current, the most frantic movement of the rudder will fail to swing it to the right or to the left. But when that boat is given an independent speed, either by the aid of a motor or hand-rowing, it will immediately answer any movement because it now has steering way, as it is called.

It was also obvious that the general outline of the aerial vessel depending upon the ascensional effort exerted by gas for its lift, would need to undergo intimate study. In this instance the mass, as represented by the plane vertical section of the balloon, is considerable, while, moreover, there was every indication that the pressure exerted by the air would crush the front of the vessel in the manner of a concertina. Gas differs from a liquid in that it may be compressed. This difficulty, in the main, was overcome by giving the airship a fish-shaped form, which, for a long time, was maintained to be imperative. The German experimenter, Count von Zeppelin, disputed this contention, because he adopted the cylindrical shape, and this is

broadly what has been adopted in the aerial giants built for the British Admiralty. Although Zeppelin was criticised, and somewhat ridiculed for adopting the cylindrical as distinct from the fish-shaped body embraced by Renard, Lebaudy, Clément-Bayard, and others, subsequent events have somewhat vindicated the German experimenter's theories.

The conditions for the maintenance of equilibrium which it is necessary to fulfil in the airship are broadly similar to those essential to the perfectly stable aeroplane. When the vessel is floating freely, or normally, in the air, its longitudinal axis, that is to say the centre line of the body from nose to stern, should be perfectly horizontal. If this end be fulfilled, then the vessel must be in a condition of perfect equilibrium, because the two forces which ensure the maintenance of this position—the upward vertical thrust, or lifting effort, and the downward pull due to its weight or gravity—are passing through the centre of gravity. If this continuity of the line of the opposing forces be broken, the vessel must tilt in the longitudinal direction, the inclination continuing until the two opposing forces come into line. What is more vital is that this equilibrium must be maintained during forward travel, otherwise the vessel is likely to indulge in disconcerting pitching. It must only be subject to intentional disturbance through the manipulation of the elevating plane or aileron attached to the tail, according as to whether the helmsman wishes to ascend or descend.

In the "dead" balloon which, having no independent speed, is merely the sport of the air, variation in the vertical plane, or change of altitude, is effected either by releasing the gas or by discarding ballast. It will be seen that by

releasing the gas the ascensional effort suffers certain diminution, and the downward gravitational pull due to weight being in excess of the upward thrust, the balloon must fall, continuing to do so until it reaches the altitude at which the two forces once more become equal. Similarly, when ballast is discarded, extra effort is given to the lift by reduction of weight, inducing the balloon to rise until it reaches the level where equilibrium once more becomes adjusted. But such methods would be impracticable with the commercial navigable airship, although the practice would be followed in case of emergency, but only as a last resort. Variation in altitude is effected mainly by manipulation of the elevator. If this be inclined, the increased resistance offered to the air serves to depress the stern and to lift the bow, thereby assuring ascent, while descent is secured by depressing the vertical rudder in the opposite direction, which forces the stern upward and dips the nose a corresponding degree.

Experience has proved that the most satisfactory airship, at all events for what might be termed the big cargo carriers—the freighters of the air—is what is known as the rigid type. This is a wonderfully impressive creation, as may be gathered from perusal of a subsequent chapter. It is necessary to provide the craft, as in its counterpart upon the sea, with a stiff and substantial backbone or keel, while the gas is carried in a number of inner but subsidiary balloons. But the adoption of the rigid form of construction has served to elucidate one searching problem—the disposition of the propelling force as represented by the propellers. In the case of dirigibles, where the car is supported by a flexible triangular suspension system, being slung some distance below the envelope, the setting of the driving effort to overcome the sum of the re-

sistances of the air exerted upon the inflated envelope and car with its rigging occasioned no little difficulty. Theoretically the position for the propeller is at a point between the car and the longitudinal axis of the envelope, but this has proved to be impracticable. Consequently the engines were mounted in the car, the propeller being placed at the bow, and the rotation of which drew the airship forward. But this arrangement only permitted the installation of a single screw, as in the case of our "Blimps."

As the dimensions of the vessels increased, it became necessary to mount additional motors and propellers to obtain the high driving effort necessary to force the mass through the air. So the tractor system was abandoned in favour of the pusher method, in which the propeller is mounted at the rear of the car, the rudder, which had heretofore been set at the stern of the suspended car, being transferred to the envelope. This arrangement enabled two sets of motors and propellers to be installed, side by side, after the manner practised with a twin-screw steamship. When it was found necessary to utilise still greater power to secure higher speeds for the bigger and heavier rigid types, it was found possible to mount several engines and their propellers in line. Thus the R34, of approximately 2,000,000 cubic feet, with a lifting capacity of sixty tons, and a total weight ready for the air of twenty-six and a half tons, is fitted with five Sunbeam engines, each developing 275 h.p., the fore and aft disposed upon the central line, while the two central propellers are set side by side.

I have stated that the British airship follows the lines of the German Zeppelin. This is scarcely correct. The German craft are truly cylindrical from end to end, with a conical-shaped prow and stern to obtain the stream-line effect. The

lines of the latest British ship are more symmetrical and fish-form, to reduce the resistance to the air to a far greater degree than is possible with the true Zeppelin form. The nose has a more attenuated and graceful curve, while the stern has a more pronounced and longer taper. It really represents a compromise between the truly cylindrical Zeppelin design and the fish-form favoured by the French. Marine practice, in its application to the air and steam-line effect, has been followed so far as the conditions would permit. The same characteristic applies to our aeroplanes, which are distinctly British in design, the stream-line effect which assures the minimum of resistance to the air being carried to a fine degree.

Incidentally, the comparison between 1909 and 1919, a period of ten years, in the matter of airship design, affords interesting reading. The *Deutschland,* the crack Zeppelin of 1909, was approximately 500 feet in length, of 700,000 cubic feet capacity, and was fitted with three motors developing in all 330 horse-power, giving a maximum speed of about thirty-five miles per hour. The British giant of 1919, which negotiated the Atlantic, is 643 feet in length, is inflated with nearly 2,000,000 cubic feet of gas, is fitted with motors having a total output of 1,375 horse-power, and has a maximum speed of forty-seven knots—about fifty-three miles—per hour, with full load of sixty tons at normal maximum engine speed. When one bears in mind that five years previously Britain did not possess a single rigid airship, it will be recognised that progress in the design and construction of the aerial liners by this country has, indeed, been extraordinarily rapid, and the end is not yet in sight. Far bigger, heavier, and more powerful airships have been, and still are being, planned, of which further details are given elsewhere.

CHAPTER III

The Man, the Machine, and the Air.

IN our enthusiastic appreciation of the efforts of our aeroplane and airship designers, and the prowess of our airmen we are disposed to talk confidently about the conquest of the air. But has the air really been mastered? It is a subtle force, and capable of playing many strange and unexpected tricks. It is these vagaries which are liable to upset the most careful of our calculations and to confuse our conceptions and knowledge. The situation was very neatly expressed upon the occasion of the transatlantic voyage to New York and back by airship in the epigram that, viâ the air, "Britain is farther from America than America is distant from Britain." This sounds paradoxical; but it serves to emphasise the fact that the wind still holds the whip-hand. For instance, while, generally speaking, it may be said to favour flying eastward across the Atlantic, it is certainly antagonistic to similar efforts in the westward direction. If further evidence of this circumstance be required, it is forthcoming in the efforts made to subjugate the Atlantic by aeroplane. The heavier-than-air machines, which set out to achieve the victory, and incidentally to win a tempting financial reward, were hung up in Newfoundland owing to absence of "favourable weather." Of the six attempts made to accomplish the apparently impossible, four recorded failure. So far as flying from Britain to the other side is concerned, but little

encouragement has been given. Only one aeroplane attempt has been made, and that ended in disaster before the first lap of the journey had been covered.

The air is still supreme. Weather beats the man. We have a very long row to hoe before we shall be able to fly where and when we will. Of the two systems competing for recognition as a commercial force of established value, the airship, at present, undoubtedly holds the advantage, and is the more promising vehicle for aerial locomotion. The aeroplane appears to have been brought to a point beyond which it seems impossible to advance. Under war conditions it undoubtedly held an overwhelming advantage; but in so far as commerce is concerned its future appears to be somewhat doubtful.

The stage has been reached where the aeroplane can only secure recognition by establishing its revenue-earning capacity. It must be developed very extensively before it can hope to compete with its lighter-than-air rival as a carrier either of passengers or freight. As at present designed, it cannot convey such a paying load. Recent mathematical deductions, of an interesting character, which have been made, show that an aeroplane, capable of competing with the contemporary dirigible in regard to earning capacity would need to have a tip-to-tip wing span exceeding 600 feet. In other words, the span of the wings of the aeroplane would have to be equal to the length of the competitive dirigible. One has only to reflect a little to grasp what enormous engine power would be required to drive such a huge dynamic flying machine through the air. This serves to bring home the nature of the contest existing between speed and weight—the alpha and omega of aeroplane design. Even our aero-motor designers appear to be more impressed with the future

for the dirigible. They have forged ahead of the aeroplane in the construction of powerful units of power—units which are far too large and heavy for the contemporary aeroplane, but which are eminently adapted to the propulsion of the dirigible.

The difference between the two systems of aerial locomotion is readily explicable. As the dimensions of the aeroplane are increased, its efficiency falls. On the other hand, as the dimensions of the airship are increased, its efficiency rises. Increase in the dimensions of the airship augments lifting effort by the cube, but resistance to the air only by the square. For instance, we will suppose we have an airship measuring 1,000 feet in length by 100 feet wide and 100 feet high, and propose to double these dimensions. In this way we shall get an airship 2,000 feet long by 200 feet wide and 200 feet high. But in doubling all the dimensions we do not double the capacity or lifting effort, but increase it by the cube, volume being equal to length multiplied by width multiplied by height. The volume of our first airship was 10,000,000 cubic feet (1,000 × 100 × 100), while that of the second airship will be 80,000,000 cubic feet (2,000 × 200 × 200). Consequently, although we only actually increase the dimensions twofold, we increase the volume or lifting capacity eight times, 8 being the cube of 2. But we do not increase the resistance offered to the air eight times. The area exposed to the air in the direction of flight is merely the width multiplied by the height. This, with our first airship, is 10,000 square feet (100 × 100). In the second airship it is 40,000 square feet (200 × 200), so that resistance is only increased by the square, 4 being the square of 2.

Accordingly, the general lines of the shape of the airship having been scientifically determined and more or less

settled, lifting effort must always be in the ascendancy and proportionate to any increase in the dimensions of the vessel. It is impossible to deprive the airship of this advantage. With the aeroplane a diametrically different result is attained.

In the light of this knowledge it is only natural to anticipate a rapid development of the dirigible, particularly for long distance and trans-oceanic traffic. But high speed such as we have become accustomed to identify with the aeroplane will not be attempted. Speed demands power and power costs money. Therefore, we may rest assured that the airship designer, in his desire to secure the utmost revenue from the conveyance of passengers and freight, will always determine the motive power issue strictly from the economical point of view. He will seek to give that speed capable of showing the most satisfactory return.

The term speed in its application to aerial craft is somewhat misleading. When we, living on the ground, talk of speed, we estimate this factor in relation to the ground; but to travel in the air the ground in relation to speed does not exist. Aloft, speed means the difference between that of the wind itself and that of the flying machine due to the effort of its engines, and is a variable factor according to the direction in which the vessel is travelling. For instance, if an airship can travel at 50 knots, but encounters a wind blowing directly against it—a head wind—at 25 knots, the actual speed of the vessel is not 50 knots, but only 25 knots, because the velocity of the adverse wind, 25 knots, must be deducted. If the engines of the airship were stopped, the vessel, now virtually a balloon, would be caught by the wind and be carried along with it; that is, backwards, at 25 knots the speed of the wind. On the other hand, if the wind

be blowing directly astern, and in the same direction as that in which the airship is travelling—what is called a following or favourable wind—the speed would be 75 knots, being the speed of the ship plus that of the wind (50 + 25 knots).

I have drawn attention to this influence of the wind upon movement in the air in connection with the aeroplane; but it is a factor which must be regarded in its true light, especially in connection with airships, inasmuch as it is apt to provoke many misunderstandings. The real speed of any flying machine is what it is able to attain by virtue of its propelling machinery if moving steadily in absolutely still air—a dead calm—which is seldom encountered. This speed, whatever it may be, is known as the *independent* speed of the flying machine, and is subject to deduction or addition, according to the direction in which the wind is travelling and the effect it is exercising upon the forward movement of the craft. It is a variation of the old problem of the fly in the railway carriage flying at eight miles an hour, in the same direction as the express train travelling at sixty miles an hour, with which we are familiar, and which is, or was, a favourite "trap" in the examination paper.

The wind is estimated according to what is known as the Beaufort scale, wherein the wind is divided into twelve broad classifications, each of which is given a relative value and distinctive number.

According to this scale, if an airship, supposing its prow were a square plane measuring 100 by 100 feet, were to encounter wind force "No. 4," coinciding with a moderate breeze, blowing directly head on, it would be called upon to battle against an adverse force of 15 miles per hour, while the total pressure against which it would be pitted, namely 0.67 lb. per square foot of its surface, would amount

THE BEAUFORT SCALE OF WIND FORCE.

Beaufort No.	*General Description.*	*Characteristics.*	*Wind Force lb. per sq. ft. Pressure on Normal Plane.*	*Miles per Hour.*	*Feet per Second.*
0	Calm	Smoke rises vertically	0	0	0
1	Light air	Direction of wind shown by smoke drift, but not by vanes .	·01	2	3 5
2	Slight breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind	·08	5	8·5
3	Gentle	Leaves and small twigs in constant motion; wind extends light flag	·28	10	15
4	Moderate breeze	Raises dust and loose paper; moves small branches	·67	15	23
5	Fresh breeze	Small trees in leaf begin to sway; wavelets form on inland waters	1·31	21	32
6	Strong	Large branches in motion; whistling heard in telegraph wires . .	2·3	27	41·5
7	High wind	Whole trees in motion; inconvenience in walking against wind	3·6	35	51·5
8	Gale	Breaks twigs of trees and generally impedes progress	5·4	42	62 5
9	Strong gale	Slight structural damage occurs, chimney-pots and slates removed	7·7	50	74·5
10	Whole gale	Seldom experienced inland; trees uprooted; considerable structural damage , ...	10·5	59	87
11	Storm	Very rarely experienced; accompanied by widespread damage	14	68	102
12	Hurricane		Above 17	Above 75	Above 110

to 6,700 pounds ($100 \times 100 \times .67$), or approximately 3 tons. But if this adverse wind were No. 10, which, by the way, is sometimes experienced upon the Atlantic, especially at certain times of the year, the airship would be called upon to struggle against a wind having a velocity of 59 miles an hour, while the pressure exerted upon its vertical plane superficies would be no less than 105,000 lb. ($100 \times 100 \times 10.5$ lb.), or nearly 47 tons.

The air is capable of upsetting calculations in another direction. I have narrated in detail something concerning the wonderful development that has been made in regard to the aeromotor, and the high standard of perfection coupled with reliability, durability, and endurance to which it has been brought. Possibly, to the uninitiated, the actual work of designing the high-speed explosion engine for aerial duty may not appear to be a very distinctive task, seeing that it has been directly evolved from the motor-car. Adaptation may even be regarded by some as being confined to the paring down of weights, and the discovery of other and lighter metals to take the place of those generally utilised. As a matter of fact the designing of the aeromotor bristles with peculiar complexities—problems which are not encountered in any other field of application. For instance, the motor-car designer, in carrying out his ideas, is not harassed by considerations of air density, or pressure, upon the performance of his engine. The chances are that he never gives a thought to this issue, merely because it does not arise, the air-pressure upon the ground being constant, or at all events so slight in variation as to be negligible. Even if the car be called upon to traverse an Alpine pass, air density may safely be ignored so far as the motor itself is concerned, although it may involve adjustment of the carburetter. But

for air duty, the altitude at which the engine is designed to work plays a very conspicuous part; it affects design to a very remarkable degree. An aeromotor develops 1,000 horse-power in the aerodrome upon the seashore. But lift that engine to an altitude of 10,000 feet, and set it going once more. It does not develop a 1,000 horse-power now; the output has dropped to 730 horse-power. By lifting the engine 10,000 feet, all other factors remaining constant, 270 horse-power has disappeared. Lift the aeromotor a further 10,000 feet to 20,000 feet altitude, and we notice that the power delivered depreciates still more. It does not exceed 535 horse-power at this level; it has lost a further 195 horse-power. That is to say, at an altitude of 20,000 feet an aeromotor will only give about one-half of the power that it will deliver at sea-level.

Such is the trick which density of the air plays upon the aeromotor, and it was one with which the designer had to wrestle very seriously in designing engines for war-service. Fighting conditions and anti-aircraft defensive measures forced the fighting bird-men to altitudes ranging from 15,000 to 20,000 feet. It involved considerable care and study upon the part of the designer to ensure a machine which was highly efficient at 1,000 feet to show an equal efficiency at the extremely high levels. Accordingly, during the latter months of the war, an engine, and for that matter the aeroplane itself, was not judged according to its capabilities at 1,000 feet or near the ground, but for its performance at 10,000 feet. This was regarded virtually as the unit.

Of course, it will be argued that under commercial conditions the aeroplane will never be forced to such altitudes as were common to military duty, and that the density of the air will never be able to exercise such an adverse

influence. But such reasoning is dangerous and fallacious. An aeroplane is making a trans-oceanic passage, or, perhaps, trans-continental journey, involving negotiation of lofty mountain ranges. A dense fog persistently prevails, and the aviator loses all sense of direction. He desires to ascertain his position, and he can only do so by climbing and climbing until he is able to secure a position above the fog, or a hole in the blanket affording him a glimpse of the sun to take his bearings and to correct his course. But in so doing he may have to climb to 12,000 feet. Unless his engine has been designed along the correct lines the climb is likely to prove disastrous; possibly it may prove to be impracticable. It will be remembered that in his flight across the Atlantic, Sir John Alcock was compelled to rise to 11,000 feet, at which level his two 350 horse-power motors, presuming the rated power was given at ground level, fell to about 256 horse-power each, a net loss on the two engines of 188 horse-power. Crossing lofty mountain ranges, such as the Cordilleras in South America, the Rockies in the United States and Canada, and the Alps in Europe is attended by similar loss of power. In the course of his flight across the Andes, in the 110 horse-power Bristol monoplane, during which the Chilean aviator, Lieut. Cortinez, had reached 20,000 feet, the engine thus only gave about 58 horse-power, presuming the rated 110 horse-power was obtained at sea-level. Consequently it will be seen that this falling-off of power at high altitudes exercises its adverse influence in civilian operations. All things considered altitude must be accepted as the governing factor in contemporary aeromotor design. The tendency is to resort to higher compressions in the engines to secure augmented output per cylinder for given dimensions, and obviously if the air be rarer it is impossible

to obtain the requisite compression in the cylinder to get the designed power output.

Although the circumstance is not always apparent to the eye, the air is full of "dangers to navigation." There are "bumps," "rapids," "whirlpools," and other aerial counterparts of dangers freely encountered upon the ocean, our lakes and rivers. The air is always in motion. We speak of a calm day, and describe atmospheric quiescence as being "without a breath of wind." But that is merely a relative term. The air may not be moving laterally, but it will be in action in a vertical direction, the hot air rising in currents of varying velocity at one point while cold currents are circulating at another point to take the place of that which, by virtue of its heated condition, has ascended to the higher levels. The aeroplane is more susceptible to these variations of air movement in the vertical plane than the airship, for the simple reason that where they exist less density or pressure is encountered. From the aeroplane point of view, a sudden decrease in the upward vertical thrust, such as is encountered when passing into one of these hot channels of air, is somewhat disconcerting, and calls for prompt correction, the natural tendency, of course, being for the machine to fall. But the decreased density not only affects the sustentation of the planes; it influences the power developed by the motor as well, since the effect is precisely similar to that encountered at an extreme altitude, where, as I have already described, the reduced pressure, or density, brings a falling off in the power, inasmuch as the desired degree of compression in the cylinder cannot be maintained. This is what happens when the machine enters a vertically rising column of heated air, and the motor speedily reveals the effects of this diminished air density.

When the wind is rushing over the surface of the earth, even at a moderate speed, it is thrown into a condition of wild confusion. Trees, houses, humps, hillocks, and other projections obstruct its flow, and so it eddies and fusses round these obstacles as the water of a river swirls and swings round a snag or rock in its path. True, the disturbance is only more or less local, but at the same time it exercises certain repercussive effects to an appreciable altitude, though with diminishing force, until at last it becomes entirely dissipated, as the radiating waves produced by a stone thrown into a pond become attenuated and finally disappear as they travel towards the bank, or become absorbed by the persistent and stronger wavelets created by the wind.

But the one enemy encountered in the air which the aviator—in common with the mariner, the express railway locomotive driver, and even the motorist—regards with the greatest feelings of dread, is fog. It renders him far more helpless than his contemporaries in the other fields of locomotion. All sense of direction, and situation, and even behaviour of machine, becomes confused. The greatest danger is probably drift. Although the scientist has succeeded in devising a variety of wonderful instruments to guide the aviator upon his way, means of calculating drift have proved too baffling to be overcome. A certain degree of drift can be registered, but it is a doubtful quantity, and is just as likely to be hopelessly wrong as uncannily precise. A powerful wind will blow a flying machine out of its line of flight, but under such conditions the atmosphere is generally clear, enabling bearings to be taken to permit correction of course. When a dense fog prevails the aviator is impotent. The only escape is to climb until the bank of fog can be topped, when obviously a reading of the sun will enable

the course to be set readily; but, in some instances, these banks of fogs extend to altitudes quite beyond the ascensional capacity of the machine.

Fog presents another danger. This is the liability of the machine to career in a circle, all unconsciously to the aviator, who labours under the delusion that he is ploughing along a continuous level straight course. But it has been demonstrated time after time. Aviators have related how they have plunged into a dense cloud, which may be likened to a thick fog, and have been surprised to find upon emergence that they are at the point at which they entered the bank, having described a complete circular flight.

This tendency to move in circles is by no means confined to the air. If one be stranded on a desert, and there be no available means of guidance, such as the sun or other bearings, one will tramp a circle, although imagining that a straight course is being followed. It is the same in the bush, as the author knows from experience, when one is deprived of all sense of direction, and the circle described would appear to tend towards the side of the body upon which the individual is naturally disposed to depend. That is to say, the circle will be to the right in the case of a right-handed person, and to the left with one who is left-handed. As upon the ground and upon the sea, where rowing follows similar circular lines, so in the air, although the aviator will vehemently maintain that he has not moved his rudder the whole time he has been in the cloud or fog-bank. So far as the air is concerned, there is doubtless an unconscious accentuated pressure of the control to swing the machine in the direction coinciding with the side of the body which is most extensively utilised, and this gradual circling will continue so long as the pressure is constant. In actual fact it

is not a true circle, but rather a spiral, which exercises the tendency to delude the individual concerned somewhat more effectively.

So far as the air is concerned, the tendency to describe a circular route when deprived of all sense of direction does not constitute the most alarming feature. The foregoing is manifested in the horizontal plane. But as the flying machine has command of movement in the three dimensions, it is disposed to turn a circle in the vertical plane as well. That is to say, an aviator will plunge into a cloud or fog-bank, and upon emergence therefrom will not only find himself at the point where he entered the exasperating danger spot, but upside down. Consequently, two circles have been unconsciously described in the two distinct planes, and that without the aviator being a whit the wiser, which suffices to prove how completely fog and cloud blunt the senses.

Since the aviator has been trained to consult his compass freely, he has been able, to a certain degree, to counteract this circular travel and inversion; but the compass must not be accepted as an infallible guide. When first introduced during the war, when the necessity to loop the loop obtained, the aviator levelled a complaint against his trusty friend because the needle was thrown off its pivot as a result of the inversion. Thereupon the instrument-maker set to work to build a compass capable of working efficiently whether the aeroplane was travelling upon an even keel or upside down. To-day, under commercial conditions, there is no need to throw an aeroplane upon its back, and so the compass is assailed because it works unconcernedly irrespective of the position of the machine. This tendency towards inversion and means for notifying the aviator thereof in a definite and infallible manner has not yet been fully over-

come; it is a problem which demands complete solution in the interests of safety. Nor does the compass completely protect the aviator against aimless wandering in a circle, although, if he be accustomed to consult his guide freely, and has taken due precautions to protect it against disturbance, the causes of which are many, he will speedily observe when he is out of his course. But even this would-be guidance becomes nullified if, meanwhile, the machine has become inverted, because the compass will probably show a correct reading, or rather one which would be correct were the aeroplane travelling on an even keel.

I have described how, in certain essential aspects, the dirigible holds the advantage over the aeroplane by virtue of the fact that the "lift" to the vessel is due to the utilisation of a gas lighter than the air, wholly and exclusively for this purpose. But the benefit attained in the one direction is lost in another. Hydrogen is a magnificent and servile servant, but a terrible and exacting master. Its explosive properties, when mixed with air, constitute a grave danger. The ideal lifting agent for the dirigible would be one having the same lifting effort as hydrogen, but as inert; that is non-inflammable, as nitrogen. Unhappily, there is no such gas known to the Periodic Law. The nearest approach is helium—the gas which abounds in the sun, and which has been found upon this sphere in limited quantities. This gas is absolutely non-inflammable, or inert, although, unfortunately, it is about .925 times heavier than hydrogen. In these circumstances an airship of given volume would only have one half the disposable lift possible with hydrogen; alternatively to secure the same lifting effort possible with a dirigible inflated with 2,000,000 cubic feet of hydrogen, it would be necessary to build a vessel of approximately

4,000,000 cubic feet capacity charged with helium. But such a vessel would be absolutely proof against conflagration through ignition of the gas, because helium as persistently refuses to ignite as carbonic acid gas. In view of this peculiar inert feature possessed by helium, an effort has been made to reduce the risks attending the use of hydrogen by combining the latter with a certain quantity of helium. Precisely why this should exercise any beneficial effect is not quite clear, especially in view of the fact that helium steadfastly declines to associate with any of its gaseous colleagues. Even if mechanically combined, owing to its density, it would promptly settle to the bottom of the gas-bag with the pure hydrogen on top, in precisely the same way as vinegar and oil will apparently combine in a bottle when violently shaken up, but which will promptly disassociate themselves and assume different well-defined levels when the vessel is placed on one side.

Moreover, helium is a somewhat expensive ally for the airship. Its market price, up to a year or two ago, was about £350 per cubic foot. But recently the cost of this gas has undergone considerable reduction. A source of supply was discovered in the United States, the gas issuing from a well of natural or petroleum gas being found to be appreciably charged with quantities of this valuable element. Forthwith a plant was installed for isolating the helium, and it was found possible to obtain ultimately, with a separation process, a gas of 93 per cent. purity at the rate of 7,000 cubic feet per day. Since then the American Government has identified itself with the task of recovering the pure rare element from this natural source of supply, and entertains hope of being able to recover it at the rate of 50,000 cubic feet per day at a cost not exceeding 5d. per cubic foot. This represents

a decided reduction against the pre-war figure of £350 for the self-same quantity; but even then its purchase is likely to prove a serious item as compared with hydrogen, which, by recourse to the electrolysis of water, can be procured for approximately 10s. per 1,000 cubic feet, as against £20 per 1,000 cubic feet for helium.

Motives of expense would seem to preclude the prompt realisation of the non-inflammable and non-explosive airship. But this factor is not likely to retard the development of the dirigible. Hydrogen, though such a fearsome master, is not so dangerous as it appears at first sight. Its volatility assists its ready escape, while it speedily becomes dissipated in the air, thus becoming innocuous. Being appreciably lighter than the atmosphere, it seeks to secure its own equilibrium, and so forces its way out of the upper levels of the vessel, at a point far removed from the engines, or passengers' smoking-room, where naked lights are likely to be encountered. In certain quarters the use of hydrogen is construed as a menace, and an insurmountable obstacle to the development of the dirigible. Similar Jeremiads declaimed against the use of coal-gas in our streets and houses a century ago, prognosticating the most terrifying calamities. Hydrogen in the gas-bags of a dirigible is as safe as coal-gas in the pipes of a building so long as its dangers are respected. If leakage takes place, as is known must be the case in the dirigible, then the circumstance must be honoured instead of ignored. A wise man does not look for gas leaks in his home with a naked light, and so the use of lights upon an airship should be employed with discretion. If this simple rule be observed no greater danger will attend travel by a dirigible than would be incurred with a vessel laden to the water's edge with petroleum, the gas thrown off from which

is every whit as dangerous, but which fact, at the same time, does not preclude its conveyance in bulk by the millions of gallons across the seas, and in the company of passengers.

There is one other phenomena of the air which deserves every respect. This is atmospheric electricity. It is particularly dangerous to the dirigible, although it applies to the aeroplane in a lesser degree; in this instance, however, its dangers can be more readily circumvented, as they are localised to the petrol tank. But the airship, as I point out elsewhere, is a huge fabric of metal which is capable of absorbing an enormous quantity of electricity, becoming converted virtually into a huge static machine. Should the vessel be called upon to traverse a magnetic storm, it is likely to be charged to the limit of its capacity with electricity. It may occur unsuspectedly to the commander, although certain of his sensitive instruments would probably reveal notification of the circumstance by becoming "sticky" in their working. Unless due precaution be observed the moment any part of the airship comes into contact with the earth, a violent static discharge would ensue, and the sparking might occur at a point where hydrogen gas happened to be lurking, in which event the vessel would go up in flame and smoke. This happened to one of the Zeppelin airships before the war. But the danger can be readily averted. All that is necessary is to introduce a few wire strands into the rope which is thrown overboard to assist mooring. This might even be attached to the stern casting to which the longitudinal girders are bolted, forming a permanent connection, being coiled and stowed in the "pulpit." In this way metallic contact of the wires of the cable with the metal structure of the ship would be assured. When the free end of the cable was thrown overboard, the moment it touched the ground it

would act as a lightning conductor, leading the electricity stored in the metal fabric of the airship to earth to expend itself harmlessly.

Risk of being struck by lightning during a storm is one against which no adequate protection can be proffered except when the vessel might be over the water. Then descent to a low level and discard of the mooring rope to trail in the water would ensure complete protection of the craft, because the rope, with its wire strands, would act as a lightning conductor. The airship then would be as safe in the most violent thunderstorm as the ocean liner under similar conditions, because it would be connected to earth. But the fabrication of the trailing rope would need to be carried out along strictly scientific lines to assure the electric current having an adequate path along which to make its way to the water, where it could expend itself harmlessly. When flying overland, under such conditions, the situation would be somewhat more complex. Anchoring would appear to be the only alternative, the mooring rope in this instance also serving as the path for any electric current which might feel disposed to reach the earth via the airship. But it is the actual lightning flash which is to be feared, since it would promptly fire any hydrogen which might be exuding from the vessel. These dangers, however, while existent and worthy of consideration, fortunately are infrequent. Airships of all descriptions have encountered storms upon many occasions during the past ten years, but no loss, while actually in mid-air, has been traced conclusively to this source, with the exception of the Zeppelin to which I have referred.

Thus the struggle between man with his machine and the air is being waged, and it is not likely to come to any definite end. As soon as one menace is overcome another is en-

countered. This is inevitable. Every system of locomotion, be it upon the sea, the railway, or the highroad, carries its peculiar and distinctive hazards. They can never be completely and satisfactorily eliminated, although they can be very materially mitigated. The way of the air is no exception, and the existence of the perils, which is admitted, cannot be accepted as an insuperable obstacle to progress.

CHAPTER IV

The Structure of the Aeroplane

THE aeroplane is an artificial bird of wood, wire, warp and woof, equipped with a motor. Such a description may sound somewhat in the nature of a generalisation, perhaps, but, nevertheless, it is the impression conveyed when surveying the craft while motionless upon the ground. Nothing is to be seen but broad sweeps of fabric, forming the wings and empennage, slender cross-wires, and the elongated box constituting the fuselage, the struts between the main planes, and the chassis, which, for the most part, are contrived from wood. Certainly the eye fails to realise that possibly as many as 20,000—or more—different pieces of wood and metal have been cunningly contrived and fitted together to produce the completed machine, some of which parts are so small as to slip readily into the waistcoat pocket. And each part has been devised to fulfil some specific function to contribute to the strength, rigidity, and stability of the whole.

The intricacy of this constructional work is completely hidden. The wings glisten in the sunlight with the sheen of silk, the body is as smooth as glass, while the wires seem to be as fine as the threads of a spider's web. This superfine finish is imperative to ensure the machine offering the minimum of resistance to the air during flight. If it were not so, and all surfaces were left rough, speed would suffer severe diminution, because the displaced molecules of air would

cling to the minute projections as cotton wool to the bristles of a brush, to act as a drag, accentuating what is known as skin friction. But, by imparting the polish to the surfaces, the displaced air is enabled to glide readily along to fall into the space immediately behind the moving machine.

In order to gain some convincing idea of the volume of work involved in the fabrication of the modern aeroplane, as well as its extreme and wonderful complexity, we must strip it of its skin from end to end. We must remove the fabric from the wings and the wooden sheathing from the fuselage.

What do we find? A beautiful skeleton; a bewildering assortment of spars, ribs, and small bones of infinite variety. If we examine the structure closely we observe that virtually each section follows a common form, not in shape perhaps, but certainly in principle. Each part is in reality a girder, and it instantly recalls to mind similar work in another sphere, which is carried out upon a more imposing scale, and with which we are more familiar—the lattice girder bridge. Then we appreciate the fact that the designing of an aeroplane is essentially a task for the engineer, involving calculations for strains and stresses, both in tension and compression. The bigger the machine the more striking is the analogy, although common principles obtain, irrespective of weight, dimensions, projected field of application, carrying capacity, and speed.

Let us now dissect this wonderful foundation of wood and wire forming a biplane. But before coming to close quarters with the structure, let us assume a position a few feet away from the nose, and in line with the longitudinal axis of the machine. Then we shall notice, although it is not a feature of every aeroplane, that the wings have a "set" in relation to the fuselage. They are observed to rise at a slight angle from the shoulders of the machine to the tips of the wings, present-

ing the form of a very widely-opened letter V. The angle which the wings offer to the horizontal line drawn through the point where they are connected to the fuselage is known as the *dihedral angle;* "positive" if the inclination be upward, and "negative" if downward. The positive angle is that generally followed, and the arrangement is introduced to contribute to the lateral stability of the machine whilst in flight.

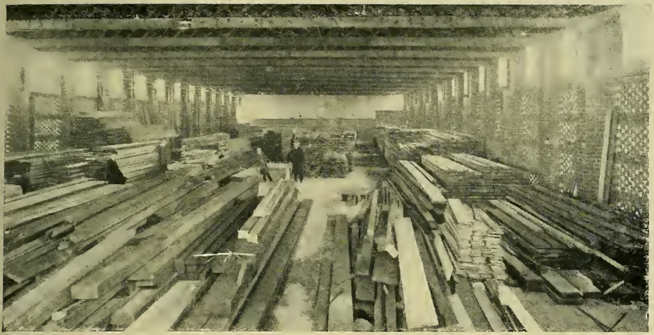
We will now proceed to investigate the formation of the wings. The right upper wing will suit our purpose, because the wings are of common design, so that the description of one will apply to all. The first "bone" is the transverse length of wood which cleaves the air when the machine is flying. This is known as the *cutting* or *leading edge,* the parallel fellow member forming the rear of the wing being called the *trailing edge.* A few inches behind the leading edge, and a short distance in front of the trailing edge, respectively, is a heavy wooden member, stretching from one end of the wing to the other. These are the *main spars* and, in reality, constitute the foundation of the wing's structure. As may be supposed, they are of substantial dimensions, and occasionally are fashioned from a solid length of timber, slightly channelled where possible, to effect a certain saving in weight without imperilling strength. The beam behind the leading edge is known as the *front main spar,* while its fellow is known as the *rear main spar,* and the former is slightly the bigger of the two. By means of these two massive members the wings are bolted to the fuselage.

The spars and edges are connected together and held in their relative positions by the aid of *ribs.* These ribs, which are connected to the two edges and main spars, follow the special design mentioned in the previous chapter, and give

to the underside of the wing, in the transverse plane—that is, from back to front—the desired concavity when the skeleton has been clothed with fabric. If one of these ribs be laid flat upon the ground it will be found to follow somewhat the shape of a hockey stick, but with a much flatter curve. It tapers at both ends, that to the rear being long and gradual, while that to the nose is sharper. The thickest or widest section comes in the curve, or hump, which is called upon to withstand the greatest pressure exerted by the air. This curvature is known as the *camber*, while the straight line drawn from point to point on the under side of the rib is the *chord*.

The ribs are spaced at intervals of a few inches and at right angles to the longitudinal members. They are of extremely light construction, but to ensure the maximum strength compatible with lightness, the section lying between the two main spars is built upon the lattice principle, with the exception of the two ribs at either end, which are solid. The building of the rib itself, an extremely interesting piece of work, is described in greater detail in the following chapter. At intervals throughout the wing other members of square or rectangular section, but smaller, are introduced, to contribute to the greater strength and rigidity of the whole. Those running transversely, *i.e.* from leading to trailing edge and parallel with the ordinary cross pieces, are known as *compression ribs*, while the similar longitudinal members laid parallel to the main spars are called *stringers*.

By introducing the ribs the wing is really divided into a number of shallow box-like compartments, and we now find that additional strength is imparted to the whole by means of wires. This bracing is confined to the area lying between the two main spars, to which the wires are anchored by the


Timber store where all wood is carefully inspected, tested, and stored.


The wood-working shop.


Girls setting ribs and cross-bracing forming the wings.

AEROPLANE-BUILDING AT THE CROSSLEY MOTOR WORKS

aid of turnbuckles. These wires are carried from corner to corner—that is, in a diagonal direction—forming a series of *X's*, side by side, in the plan of the wing. The point of intersection, that is, where the wires cross, is the centre of an intermediate rib, so that every two compartments form a unit for wire-bracing purposes. To the uninitiated, the reason for the incorporation of these wires may seem somewhat inscrutable, but they perform important specific functions. The wires running in an outward direction from the body of the machine—that is, from rear spar to front spar—are the *flying drift wires*, while those extending diagonally in the reverse direction, namely, inwards towards the body and from front to rear main spars are the *landing drift wires*.

At the extreme inner corner of each wing the continuous plane surface is interrupted by the hinged flap or *aileron*, whereby the lateral stability of the machine is maintained as already described. The ailerons of the upper and lower wings are connected, and are actuated by the one control wire extending to the "joy-stick," so that they shall move in unison, up or down, as desired, and to an equivalent degree. When resting normally, these ailerons form part and parcel of the wing. It is just as if, after the wing has been built, a corner section were cut out and then replaced, but on hinges. The whole of this skeleton is enclosed in a skin of fabric, both above and below, secured in position by means of rivets and stitching, to present a smooth, even surface, similar to that of the feathered wing of the bird, to the air.

In view of the fact that the wings constitute the most vital part of the machine, being called upon to support the weight of the motor, fuselage, passengers, and other impedimenta, it is imperative that they should be built with extreme care, and, at the same time, offer the maximum of strength con-

sistent with the minimum of weight. In the case of the biplane, with which we are dealing, the wings are divided into pairs, known as *right* and *left*, or *starboard* and *port*, pairs respectively, in relation to the pilot when facing the direction of travel, the upper and lower planes on either side forming a pair.

The upper and lower wings are spaced a prescribed distance apart, and are maintained invariably in that position by means of rigid lengths of wood known as *interplane struts*. These are set in pairs, in line, in the direction of travel. Those forming a pair are spaced the same distance apart as the main spars in the wings to which they are secured. As a rule there are two pairs on either side of the body, and each strut is given its distinctive name for purposes of ready identification, and according to position in relation to the pilot as follows: *Starboard inner front interplane strut, starboard inner rear interplane strut, starboard outer front interplane strut, starboard outer rear interplane strut.* The same nomenclature is followed in relation to the other side, only port is substituted for starboard. Thus, port inner rear interplane strut would signify the strut nearer the trailing edge of the left wing. In all terms relative to position in connection with the aeroplane, those presented to the pilot while in his seat are implied, *i.e.* right, signifying the pilot's right-hand.

When the machine is surveyed from the front, the wires appear to be stretched somewhat haphazardly in all directions in the vertical plane; but, as a matter of fact, each line of wires fulfils some defined purpose. The diagonal wires between each pair of inner and outer interplane struts are *incidence wires*. Those running upward and outwards are the *flying wires*, the principal function thereof being to transfer the lift of the planes to the body or other part of the structure. Those

running in the reverse direction, downwards and outwards, are the *landing* or *anti-lift* wires, because they resist the forces in the direction opposite to lift, take up the weight of the wings when the aeroplane is resting on the ground, and also absorb landing stresses.

In the early types of biplanes, such as those flown by the Farman Brothers and their contemporaries, the planes were connected by canvas partitions dividing the wings into boxes or cells. This vertical walling has been abandoned, but the formation then presented is preserved in name, the box-like space between each adjacent pair of interplane struts being known as *cellules*.

The distance the upper and lower planes are spaced apart is the *gap*. The reach from the point where the plane is bolted to the body or centre section is the *length* of the wing, while the distance from leading to trailing edge is the *depth*. The *centre section* represents the part of the plane lying between the right and left wings, immediately over the fuselage, which, as a rule, is perfectly horizontal, while the overall distance from one wing tip to the other forms the *span*. In some biplanes there is no dihedral angle, the planes being continuous from end to end and perfectly straight. In this instance the fuselage is bolted to the centre section struts and rests on the centre of the lower plane. Occasionally, as for instance in the Short biplane, the lower wings are shorter than the upper planes, to save the wing-tips from possible injury by the waves while riding at anchor, the top plane in this instance having an overhang on either side in its relation to the bottom plane.

Before leaving the wings, we will walk to the side to survey them from one end. Then we observe that the two planes are not set one above the other with the respective

leading and trailing edges in a vertical line, but that the leading edge of the lower plane is set somewhat behind or in advance of that of the upper plane. This disposition is the *stagger* of the planes, and the degree to which it is carrried out varies somewhat widely. The backward stagger of the planes was particularly pronounced in the "Airco 5," the front edge of the upper plane being almost immediately above the trailing edge of the lower plane. The arrangement adopted in this machine aroused considerable comment from the degree to which it was carried, since it imparted a truly startling effect; but it was adopted in order to afford the pilot an increased forward and vertical field of vision, and in this connection proved eminently satisfactory. In many machines, however, staggering is scarcely favoured at all. We may also notice that the chord of the plane describes an upward angle from the trailing edge to the horizontal. This is the *dihedral angle, angle of incidence*, or *angle of attack*, meaning the angle a plane makes with the direction of its motion relative to the air.

The body, variously known as the fuselage, car, or nacelle, follows the rough form of an elongated box, tapering gradually towards the stern, and having a sharply tapered blunt nose. If the propeller be carried in front, it is mounted in the nose of the frame. Then comes the motor, followed by the pilot's seat or cockpit, and passenger accommodation behind. The fuselage, while built as lightly as possible, is yet of exceeding strength from the system upon which it is constructed, and is freely strengthened by vertical and transverse struts with diagonal wire bracing. When the propeller is placed in the front, the aeroplane is of the tractor type, because the screw, by its rotation, draws the machine through the air. If the propeller be disposed behind the wings, the

aeroplane belongs to the pusher class, since the revolving screw forces or pushes the machine through the air.

At the extreme stern comes the empennage or tail unit. Set vertically upon the back of the fuselage, in line with the rudder when the latter is normal, then forming, as it were, part of the latter, is a small vertical plane or *fin,* introduced to increase the stability of the machine. At right angles to this fin, and projecting from the tail on either side, is another fixed fin of similar design and shape. These form the *tail plane,* and serve to assist in stabilisation in the horizontal or lateral direction. These vertical and horizontal planes constitute the tail proper of the machine, and play an important part in the maintenance of balance, acting in the self-same capacity as the tail of a kite. To the rear edge of each horizontal tail plane is hinged a small flap or aileron, the *elevators,* connected by control wires to the "joy-stick." They can be moved up or down, as desired, to control and steady the aeroplane in the direction of travel. Finally, there is another plane, set perpendicularly to the main supporting surfaces or wings, and which is movable about its axis. This is the *rudder,* controlling movement to the left or right, the wires from which are led to the extremities of the bar set athwartships and centrally pivoted in the pilot's cockpit, and which is actuated by the feet.

Projecting from the underside of the fuselage, towards the tail, is a curved leg. This is the *tail skid,* which assists in absorbing the shocks incidental to landing, and which, by dragging along the ground, acts as a brake, and thus slows up the machine. Towards the prow of the aeroplane, and mounted upon the underside, is the chassis or *undercarriage.* It is substantially built, because it not only serves to carry the machine and to support it while resting upon the ground,

but also assists in the ascent, and absorbs the shocks arising from landing. The undercarriage is built up of wooden struts, strengthened with bracing wires, and is equipped with a heavy axle to carry the wheels. The number of wheels introduced varies according to the dimensions and weight of the machine. A small aeroplane may have two, while a big machine may have as many as eight wheels. In the case of the seaplane, the wheels are supplanted by floats, for reasons which are obvious. The wheels are shod with massive pneumatic tyres, nine or more inches in diameter. For taking up the shocks incidental to landing, *shock absorbers* are introduced, being contrived from elastic or india-rubber for the most part, this material having been found highly efficient for this application, although springs and oil are also employed.

Our dissection of the aeroplane is now completed. Of course, if we felt so disposed, we might conduct this task in greater detail; but I think the foregoing will suffice for our purpose, acquainting us with the principal terms used in its design. From what has been related, it will be recognised that the contemporary artificial bird is a far more complex piece of apparatus than the mere observation of the machine, while at rest upon the ground, would tend to convey. In the next chapter we will follow the construction of the heavier-than-air machine through its numerous stages.

CHAPTER V

The Construction of an Aeroplane

SCIENTIFIC accuracy and beauty of design, as conceived by the engineer, would count for naught were the creator's handiwork translated loosely from the abstract, as represented by the drawings, into the concrete, as revealed by the living machine. The workmanship in the fabrication of each of the 20,000 or more separate parts entering into the modern aeroplane, be they large and straightforward, or small and finicky, must be above reproach, because the imperfection of a single tiny piece may jeopardise the whole. While no chain is stronger, despite its proportions, than its weakest link, so the safety of an aeroplane in the air depends upon the excellence of the material, workmanship, and fitting of the smallest piece. If the design be right, the resultant machine will leave nothing to be desired when construction is conducted along superfine lines. The builder cannot translate an indifferent design into a perfect machine, but he certainly can convert a perfect design into a dangerous craft by the display of poor workmanship. From this it will be seen that the construction of the aeroplane demands a high grade of labour—men and women of super-skill, patience, and who are conscientious in their work.

The urgency for these qualifications is emphasised in every works devoted to this phase of activity. Inscribed in bold letters, and so prominently displayed as to catch the

eyes of those toiling at every bench, is a warning—the precise wording is varied, though the same emphatic meaning is conveyed—which runs:

> REMEMBER THAT A HIDDEN MISTAKE MAY CAUSE A BRAVE MAN TO LOSE HIS LIFE.

No error can be justified. The risk to the life and limbs of those who use the high-road of the air is too heavy to permit the slightest deviation from the rigid specifications laid down, or to admit the incorporation of the smallest integral part which is not up to standard.

During the war, owing to the insatiable demand for aeroplanes, factories devoted to the construction of this fighting arm were as densely dotted throughout Britain as blackberries upon a bramble-covered hillside in Autumn. Some were in being before war burst upon us; others were extemporised from buildings which, under peace conditions, were identified with other and more blessed phases of endeavour; and many were built during the period of hostilities to contribute to the ever-rising stream of supply. In view of this circumstance, it might seem to be invidious to single out any one establishment for a visit to witness the actual production of an aeroplane at close quarters, were it not for the fact that Lord Weir, who, during his term of office as Minister of the Air, was mainly responsible for the creation of the national flying-machine producing hives, went out of his way to individualise one of these aeroplane mills by describing it as "the finest factory of its kind in the world." So we cannot do better than to accept the opportunity to wander through this model establishment.

The factory in question not only deserved such premier recognition upon the comparative basis, but demanded more than passing notice from the circumstance that it was the largest of its character in the world, and, moreover, was regarded as a striking illustration of supernal lay-out, organisation and efficiency, as well as output. Furthermore, we learn incidentally that this particular factory is invested with a distinctive touch of romance, offering a concrete example of what this country and its barons of industry can achieve when necessity so demands, because its actual creation ranks as one of the greatest factory-building achievements associated with our military endeavours.

During the early months of 1917 the need for more and more aeroplanes induced the Air Ministry to approach the company identified with the manufacture of the Crossley motor-car with the request that it should embark upon the production of aeroplanes. At the time the existing factories were overwhelmed with orders for cars which were in demand by the War Office, as well as the manufacture of aeroplane motors. The recommendation that it should embrace the new line of production was accompanied by the stipulation that such work was to be carried out without interfering with the works in being, and their products, by one jot or tittle. Not a man was to be drawn from the benches for the new job.

The terms were distinctly onerous, but the gentleman presiding over the destinies of the Crossley motor-car is of infinite resource, makes light of difficulty, and is possessed of striking powers of organisation, while, when the occasion arises he is a hustler comparable with the most tireless geniuses of this ilk which the United States, the home of the hustler, can produce. Extensions to the existing works being impracticable, Mr. W. M. Letts, C.B.E., the gentleman in

question, decided to erect a new factory for the authorities especially for the new range of enterprise, and to this end he secured a plot of virgin ground at Heaton Chapel, contiguous to the main railway system running from Manchester to Stockport.

Speed was the all-important factor. Forthwith the drawings for the buildings were rushed through at tip-top speed, while the country was scoured for the requisite machinery. But although draughtsmen and others were called upon to work day and night, and inexorable time was driving hard, haste was not permitted to jeopardise method. The planning of the new factory, which covers 15 acres, has been carried out in strict accordance with the latest planning precepts, and is accepted as being one of the most convincing expressions of science in its application to this field in these islands. The first sod was turned in October, 1917. Within nine months the fifteen acres of land were covered with substantial permanent buildings of the most up-to-date character, equipped with machinery, and were not only in full blast, giving employment to 2,500 hands, but had turned out a round 400 aeroplanes. This was one of the smartest of the many notable feats achieved by Britain during the war. But in this particular instance, aeroplane production was denied the opportunity to get into its true stride, owing to the signing of the Armistice. However, the work accomplished serves to convey some impression of what could have been contributed to our aeroplane building efforts had the war continued, because from these fifteen acres of single-floor workshops several thousand aeroplanes would have been turned out complete and ready for the war in the air during the year 1919.

From the factory point of view, this establishment constitutes a model in more senses than one. It demonstrates how

maximum efficiency and output may be secured. The raw materials enter at the one, and the completed machines issue from the other end—an application of the wonderful system pursued by the meat-packing plants of Chicago to quite an unusual realm of activity. The main entrance to the shops is from what is a street in itself, the thoroughfare being 1,040 feet in length by 60 feet wide. Up in the lofty glass-covered roof is a travelling electric crane, capable of lifting one ton, which is able to travel from one end of the street to the other, even beyond at the lower end, to span the special railway sidings laid down, as well as to command the whole 30 feet of roadway on either side of the central overhead track. Consequently, within this space the largest and heaviest loads could be handled with ease, being picked up and set down just wherever desired. Another outstanding feature is the main shop, which must be one of the largest in this country under a single roof, seeing that it measures 1,040 feet in length by 282 feet in width. A single walk round this shop, devoted to assembling and erecting, is an invigorating constitutional of half a mile, as we discover. But as we are upon an intimate stage-to-stage journey of discovery and enlightenment, that is, following the aeroplane throughout its whole course of construction, we shall find we have completed a walking trip of a few miles by the time we reach the door through which the finished machines pass to be sped away to the Service flying grounds.

But the principle adopted contributed to the national requirements to a striking degree—namely, the production of the maximum number of aeroplanes, of unassailable quality and perfection, within the minimum of time, at the lowest cost, and with the minimum of labour, which, for such work, had become scarce at the time this aeroplane incubator was

brought into operation. The mammoth single shop facilitates supervision of the many intermediate stages, and allows the flow of work to proceed from point to point rhythmically and at the desired volume. There is no doubling back or diversion to one side or the other; the product advances direct from stage to stage in a continuous line as a river making a bee-line across country from its source to the sea.

The raw material involved in the fabrication of Mother Britannia's Stormy Petrels may be broadly divided into three classes—wood, metal, and fabric, or linen, with which the planes are covered. Of course, there are accessories innumerable either in the raw or finished state, ranging from dope and varnish, to propellers and motors. These are not made here, but are purchased complete ready for installation, being held in astonishing bulk in the stores adjacent to the precise points for their specific installation, so that the work may not suffer the slightest slowing down from insufficiency of supplies. The metal work similarly arrives in several forms, but many of the requisite accessories, such as turn-buckles, bolts, nuts and so forth are made on the spot; for which special shops, equipped with the latest tools, have had to be provided. The metal shops must necessarily be of a complete character, because the work which has to be fulfilled is exceedingly varied, including the formation of large parts by huge and powerful presses from the solid sheet, stamping, milling and automatic drilling—to mention only a few of the operations involved.

The wood arrives in the baulk. Spruce and ash are the most eminently suitable woods for the fabrication of the wooden parts of the aeroplane, such as edges, ribs, spars, and struts, but the consumption of timber to satisfy the claims of war was so enormous that one or two other woods had to

be pressed into service. Notable among these, we learn, was Oregon pine. We see baulks swung from the railway trucks to be stored in a capacious timber shed, the walls of which, we notice, are freely perforated to permit the circulation of air. Samples of wood are drawn from each consignment to be subjected to test, since in the construction of the aeroplane the golden principle "Safety First" obtains, to which I make more detailed reference in the following chapter.

But much of the wood received is in the green condition, or has only been partially seasoned. Until this requirement is fulfilled it cannot be used. Mother Nature generally carries out this task because she does it so well. But in these high-pressure days industry cannot wait for Nature. Her process, though thorough, is slow, occupying years. Science, therefore, has come to the assistance of commerce, and has perfected a means of completing seasoning to the required degree in as many hours as Nature would demand in years.

Timber conditioning is an interesting process. The baulks of timber are cut up into the desired dimensions, and the pieces are placed in huge ovens, or chambers, the air within which is raised to a certain degree of temperature. For conditioning spruce, for instance, it must be raised to 85 degrees Fahrenheit, while it may be lifted to 125 degrees for ash. The hot air evaporates the moisture or sap carried in the wood. Naturally the air within the oven becomes humid as it soaks up this moisture, and accordingly must be expelled, because it is essential to use dry air, which has an affinity for the moisture. This absorption of moisture takes place far more speedily than might be imagined. Consequently the whole of the air within the chamber has to be changed at brief intervals. In the conditioners in question we find it is changed

every 60 seconds, or 60 times an hour. But the withdrawal of moisture must only be carried to a certain degree. It is imperative that a certain percentage be left in the wood, this proportion contributing to its inherent strength. If the whole of the moisture is withdrawn it leaves the wood dry and brittle, and in this condition it would be quite unsuited for the skeleton of the aeroplane. The limit of moisture is about 14-17 per cent., at which the wood is excellently adapted for its avowed purpose. Sometimes the wood does not possess the amount of moisture desired, having been withdrawn in the natural seasoning process. In this event the conditioner, after the wood has been inserted, is charged with humid hot air. The dry wood greedily extracts this moisture from the air, the prevailing heat facilitating the process, and in this manner the moisture is restored and the wood rendered fit for the work in hand. It will be observed that conditioning acts both ways—the removal of the surplus sap from wood or the restoration of any deficiency in this connection.

Upon withdrawal from the conditioning chamber the wood is ready for working, and it is passed on to the wood machine-shop. Here are a diversity of tools, every one of which derives its driving power through belting connected to underground shafts driven by electric motors. There are machines for sawing the timber into pieces of the desired thickness, width, and length, others for moulding, fret and band saws, tenoning machines, and so on. Each specific task has its individual tool, which ensures fulfilment of the work in the shortest time with the minimum of effort. Accuracy in dimensions is assured by recourse to patterns combined with checking and counter-checking by means of gauges and other measuring devices at frequent intervals.

One machine arrests our attention because of its novelty,

and we learn that it was designed essentially to meet the demands arising from the pressure of war. This is the strut copier. Struts are freely used in the aeroplane, as we have observed in dissecting its skeleton—for spacing the wings apart, the undercarriage, and so on. They are of standard streamline shapes and dimensions. Thus the interplane struts of the biplane, of which twelve at least are required, are identical in design and size. By aid of the copier they can be turned out in rapid succession. The master strut is fashioned to dead accuracy. It forms the pattern or guide for the cutting tool, the movement of which is governed throughout thereby, so that the section of timber inserted in the machine is converted into an exact fellow of the master, conforming therewith in every detail—dimensions and forms—within a few minutes. By means of this ingenious machine the manufacture of struts has been speeded up very pronouncedly.

Watching it at work we are not surprised when we are told that it will turn out four struts while one is being shaped by hand. This machine contributed in no small measure to the accelerated output of aeroplanes. Another novel machine is the sander, which imparts just that eminently desired degree of smooth finish to the member without deforming it by the smallest fraction of an inch, and which, owing to the maintenance of uniform pressure throughout the operation, is able to fulfil the task to a finer nicety than hand-sand-papering, while, of course, it is immeasurably quicker. As may naturally be supposed from the character of the work, an immense volume of dust, chips and refuse arises from this working in wood, but this is automatically picked up in dust-collecting ducts, which whirl it away to the refuse-destructor in the boiler-house, where this waste is induced to assist in raising steam for the operation of the plant. By means of

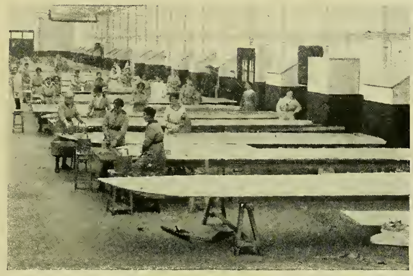
this apparatus the atmosphere within the wood-working shop is kept clear and pure, instead of being freely contaminated to the detriment of the health of the workers.

One of the most interesting corners of the factory is that where the ribs are made. These, as we have seen, are built upon the lines of the lattice girder, the idea being to secure the maximum of strength compatible with the minimum of weight. In reality the rib is built up of thin wisps of wood, which, when we pick them up for examination, appear to be too absurdly thin and fragile to support several hundreds, even thousands, of pounds in the air. Why, they are barely a quarter of an inch in thickness and not much more than an inch, if that, in width! Their manufacture is intricate and essentially a task for small and nimble fingers, so we are not surprised to see women and girls extensively employed in their production. Analysis of the rib shows two thin flanges, forming the top and bottom surfaces upon which the fabric bears. Centrally along each flange is attached a thin vertical piece of web, converting the two members into T-pieces when seen in section, the lower, of course, being inverted. These two are brought to the curvature desired, forming the shape of the rib, and are connected together by small cross pieces set diagonally, forming a lattice, attached by brads to the webs of the T-pieces and cut so as to drop within the flanges. Care is required in cutting the diagonals so that their edges may press firmly and accurately against the inner face of the flanges of the ribs, while skill likewise has to be displayed in driving the brads home without splitting the wood.

The light, dexterous touch possessed by women and girls is excellent for this work, while temperamentally they are better adapted than men to the task, because it is extremely finicky, demanding patience as well as immunity from bore-

Cutting fabric for covering wings, ailerons, and fins.

Varnishing ailerons by compressed air pistols.



Doping the wings.

Varnishing the wings.

AEROPLANE BUILDING AT THE CROSSLEY MOTOR WORKS

dom by its monotony or repetition. When completed the rib weighs but a few ounces.

Although the integral parts would readily snap in the fingers, it is surprising the amount of pressure the completed rib will withstand without suffering any visible deflection of its designed curvature, as we are able to prove to our own satisfaction. We grasp an end in either hand, and no matter how much pressure we exert in the vertical direction, we find the rib to offer complete resistance to our efforts. Of course, if we impose the strain slightly out of the vertical—a twisting stress—we bring about its collapse, although even then not so readily as we were disposed to believe possible. This experience recalls the old effort to crush an egg, even a small one, by pressure between the thumb and forefinger of one hand. So long as the pressure is exerted along the longitudinal axis the egg will stand up to the strain; it only gives way when the strain is deflected a trifle to one side of that axis.

We see how every part for the projected aeroplane, whether in wood or metal, follows a similarly careful fashioning process. There is nothing haphazard. Patterns are furnished for everything, while we observe gauges to be used as freely as the tools. Promiscuous selection of parts is made at every stage for examination and testing to see that the work is being maintained up to the desired standard of measurements and excellence of workmanship. The laboratory is probably one of the busiest and most responsible corners of the hive, because here everything is tested to destruction, records being made at intervals and the collapsed sections subjected to minute investigation to determine, if at all possible, the cause of the failure, and, in the event of it occurring at what the engineer considers to be a relatively low limit for the design

of the work or the character of the material, to discover ways and means to improve it, and thus obtain augmented strength and resistance.

In the previous chapter I have described the spars as being the foundation for the wings. In view of this circumstance it is obvious that these members should be possessed of a high degree of strength. Originally, to ensure this end being fulfilled to complete satisfaction, the choicest lengths of suitable wood were reserved for this duty—the pick of the basket as it were—while experience, which was relatively circumscribed, demanded that they should be fashioned from the solid piece. But with longer wings selection of suitable lengths of timber became somewhat more exacting, while one was denied the opportunity of determining whether the wood was sound right through. In order to obviate the use of solid pieces, the internal composition of which might be doubtful, a system of building up the spars on the box principle was made. Four lengths, say of 24 feet, or whatever happened to be the wing-length, and of a certain width and thickness, were prepared and secured together to form a girder, the interior, of course, being hollow. This practice offered the advantage of a saving in weight. But the box-spar has been superseded by what is known as the laminated spar, which, as we are able to see for ourselves, represents a decided improvement, because it gives far greater strength.

If we measure the front spar of, for instance, the DH 10, finished and set in its wing, we find that it measures 3 inches wide by 5 inches deep, and is 30 feet in length. It is built up of eight superimposed layers of wood, 3⅜ inches wide, and with a depth when assembled of 5⅜ inches in the rough. These eight pieces are glued together to form a solid beam, which is worked down to the final dimensions. Not only is

the spar built up in this manner far stronger than one shaped from the solid piece of wood, but strength is uniform throughout. The sections of wood being relatively thin—less than ¾ inch—are not likely to be faulty. Selection can be made to greater advantage. Another distinct benefit which accrues is that the arrangement permits the use of short lengths, provided they are of the desired width and thickness, which otherwise would be wasted. When odd lengths are incorporated it is the practice to sandwich them between the two upper and bottom laminations, which are in continuous lengths, because these are exposed to the full stresses of tension and compression respectively, the former strain being borne by the top layers of the beam and compression by the lowest layer. Should any joints be introduced in the intermediate five layers, care is observed not to bring them into line. They are staggered, thus eliminating any possible point of weakness as would otherwise arise were the joints brought into line. In this way wastage of wood is reduced to the absolute minimum; what may be rejected is altogether useless owing to flaws.

The one requirement in building a spar upon the laminated principle is that the layers be cut, planed and surfaced true to gauge. Under modern machine methods there is very little cause for apprehension upon this score. The system also is applicable to any shaped spar, whether it be perfectly straight or curved, the curvature, of course, being obtained by submitting the wood to steam heat while being bent. So long as good animal glue is used a perfectly sound job may be safely anticipated. Scarcely any pressure is employed to secure the firm adhesion of the laminations, the member being merely assembled in a jig and subsequently transferred to a hand-secured press to dry.

Building a spar in this way does not take much more time than is involved in the shaping of the member from the one solid piece of wood. The time normally employed for gluing up the eight layers of wood is fifteen minutes, but at the National Aeroplane Factory (Crossley Motors, Limited), owing to the efficiency and perfect organisation prevailing, the task was reduced to 12 minutes. The member is left in the press for 12 hours, and the total period of time required in making a spar along these lines, from the first receipt of the laminated sections to be cut and assembled, to the delivery of the finished article ready for building into the wing, is about 18 hours. The fashioning of the solid-piece spar—from the raw length to the finished article—occupies about 6 hours. Superficially it seems that the preparation of the laminated spar requires about 12 hours more than the corresponding production of the member from the solid, but against this must be considered the possibility of the last-named suffering rejection either upon completion, or when half-finished, from the discovery of some unsuspected defect.

Rejection after partial manufacture, or when completed, is by no means an exceptional circumstance in connection with the fabrication of the one-piece spar, because it is absolutely impossible to determine the character of the heart of the wood until the workman has worked down towards it with his tools. Furthermore, the element of doubt is always more pronounced in connection with the solid than with the built-up member, because the suitability of the wood for the laminations has been determined long before they reach the actual stage of application. Last, but not least, there is the item of wastage to be borne in mind, which is much heavier with the solid spar than with its built-up contemporary, which in these days

of costly raw material and of dubious quality is likely to be a serious item.

While the woodwork has been under way the requisite pieces in metal have undergone test and fabrication. This is work incidental to every metal-working shop equipped with automatic drilling machines, both single and multiple, presses, capstan and automatic and other lathes, so that this work does not arouse undue attention. But there is one phase of the metal-working operations which, as we see, deserves more than passing notice. Sections of metal have to be joined together, and here the conditions demand special measures being followed. The aeroplane is called upon to withstand heavy shocks, jars, and vibrations. It is imperative that the metal parts which need to be joined together should be so treated as to produce, to all intents and purposes, a solid piece, no matter how involved the design. That is to say, the *tout ensemble,* both in appearance and uniformity of strength and rigidity, should be precisely the same as if the piece were contrived from one solid piece of metal. This end is assured in a very effective manner by recourse to oxy-acetylene welding.

This is highly exacting work, owing to the fine degree to which the temperature of the flame has to be adjusted and the extreme care which has to be observed to avoid burning the metal, the heat of the flame produced being so exceedingly intense. Moreover, many of the pieces which have to be joined are exasperatingly small, and this, as we can see for ourselves, is another realm in which feminine hands and temperament excel. The light, delicate touch of the woman, combined with her patience and ability to maintain the requisite degree of diligence and care, irrespective of repetition, have enabled her to convert this into an essentially

feminine working sphere—one in which she need apprehend no competition from male labour. Before the war the suggestion that women should operate the oxy-acetylene welding jet, and that they would become proficient in the task, was regarded with extreme scepticism, if not point-blank ridicule; but experience has proved that in this peculiar craft she has no equal. Withal she is quick, as experience at the National Aeroplane Factory (Crossley Motors, Limited) has convincingly demonstrated, while the percentage of rejected work, once proficiency is obtained, is so low as to be negligible. Feminine fingers are likewise found superior for splicing the wires introduced for bracing and reinforcing the wings; while the women and girls have also proved their adaptability and peculiar capacity for carrying out many other apparently intricate and certainly wearying phases of craft identified with the manufacture of aeroplanes. In fact, the building of aeroplanes, or rather that part of the work involving the fabrication of the components, might be truly described as being pre-eminently a feminine occupation.

Naturally, the preparation of the fabric for the wings comes within the feminine province, accustomed as the woman is to cutting-out and the operation of the sewing machine, which enters so largely into this part of the work. The linen is specially prepared, being of great strength with light weight. In the raw condition it weighs 4 oz. per square yard, and each square inch is able to sustain a strain of 90 lb. without tearing. The fabric is stretched over the wings and frames of other planes such as the fin and ailerons. It is not drawn too tightly, as a certain degree of shrinkage takes place during the subsequent doping and varnishing operations, imparting to the planes the requisite drum-like tight and smooth surface.

We now pass into the dope room—perhaps the most critical part of an aeroplane factory. We are impressed by the special features incorporated both in its design and construction. In the first place it is imperative that ventilation shall be carried out along special lines. Although the dope now used is free from the objectionable features so characteristic of the early preparations to this end, it still throws off fumes which are injurious to the health of the workers. Being heavier than air it settles to the floor, and would wreak widespread havoc unless it were removed continuously and effectively. At this factory we observe the fumes are exhausted through the walls of the building into the outer air by means of electrically-driven propeller fans, set about five feet above the floor level, thereby preserving a satisfactory respirable atmosphere.

The second requirement is in regard to temperature, which experience has shown should be maintained at from 70 to 75 degrees Fahrenheit. The maintenance of the desired temperature is assured by means of twenty steam-heating elements, the room in question being 282 feet in length by 40 feet wide. Each fabric-covered part receives five coats of dope, and each coat is allowed to stand for sixty minutes to dry, so that the operation occupies five hours. By the time the doping operation has been completed the weight of each square yard of fabric has been increased from 4 to 7½ oz., the weight of the dope itself thus being 3½ oz.

The next operation is the application of the final coat of pigmented varnish. The room in which this work is carried out demands ventilation and the maintenance of an equable temperature similar to that incidental to the dope room, but as no fumes are thrown off in this process it is only necessary to change the air within the room once every twenty minutes.

One process in this department arouses our attention. This is the varnishing of the small planes, such as ailerons, fins, elevators, and stabilisators, as well as rudder. Instead of the varnish being applied by hand with a brush, as in the case of the wings, power is employed. Each girl is armed with a pistol, from the stock of which extends a flexible pipe to the varnish supply reservoir. She points this pistol at the surface to be treated, presses the trigger, and the varnish is delivered in the form of a fine spray. By moving the pistol she can apply the varnish finely and evenly over the whole of the surface, assuring an adequate uniform coating. The finish obtained in this manner is superior to that obtained by even the most dexterously and skilfully handled brush, while, of course, the time occupied in carrying out the task is very materially shortened.

In another part of this huge workshop the erection of the fuselage is proceeding contemporaneously with the fabrication of the wings. The girder-like hollow body is set upon trestles, the engine is lowered into place and bolted up to its bed plate. The petrol tank, the capacity of which ranges from 60 gallons in the case of the DH 9 to 200 gallons for its consort DH 10, is put in place, as well as the controls and joy-stick, or control-lever, and pilot's seat. The tail planes are brought forward to be erected while the fuselage is clothed with its outer thin sheathing of wood, after which painting and varnishing are taken in hand. Then follows the equipment of the dashboard with its various instruments. At this factory the wings are not attached to the fuselage, but being standardised, in common with all the other parts of the machine, there is no necessity to do so, inasmuch as they are certain to prove accurate and to bolt readily into place. Of course, if the practice were to deliver the machine by air they

would be completed to the uttermost detail, but in a factory having an output such as that of the National Aeroplane Factory (Crossley Motors, Limited), such an arrangement would involve the maintenance of an extensive official staff, ready to carry out final tuning-up and to make the acceptance trials on the spot. This might have been doné at this factory, because we observe that attached to the works is an extensive flying ground, but it has never been utilised except for the purpose of conducting trial flights with new machines.

There is one feature of the aeroplane the manufacture of which we have not witnessed during our round of investigation—the construction of the propeller. Its manufacture is not conducted at Heaton Chapel, for the simple reason that there are several firms throughout the country specialising in this work, which is a craft apart. However, a few words concerning the contemporary aeroplane propeller may not be out of place. It differs very widely from those used by the pioneers who blazed the trail of the air, although the fundamental principle was elaborated in those early days, the advantages being promptly recognised. It is built up of layers of wood, or laminations, after the same broad lines followed in the construction of the main spars, mahogany and walnut being the favoured woods; but these laminations are stepped, so that when gluing is completed the propeller has a certain semblance to its final form, the curve of the blade being roughly indicated. When the rough propeller is removed from the press some hours later it is subjected to several operations in various machines, which work it down to its final form. It is then smoothed and sandpapered, finally being finished with varnish. The propeller boss is introduced and made fast. At various stages during manufacture

balancing tests are made, the propeller being slipped upon a shaft and laid in the horizontal plane. Being mounted freely, unequal balancing would speedily assert itself by the heavier blade falling, bringing the propeller to the vertical position. It may be mentioned that the design of the curvature of the propeller blade varies according as to whether the aeroplane to which it is to be fitted is a pusher or tractor machine, the one type not being applicable to the other duty.

Every phase of human endeavour possesses its individual romance and fascination, but that identified with the construction of an aeroplane, especially when conducted in accordance with the latest dictates of efficiency and organisation in association with scientific factory planning, as is so powerfully exemplified at the Heaton Chapel Works of Crossley Motors, Limited, invests the craft with unusual distinction. Such an establishment as we have been privileged to visit, and the more impressionistic features incidental to operation which are set down, serve to bring home the immense strides which have been made in the realm of dynamic flight during a decade. Finally, it serves to emphasise very conclusively what we, as a nation, can do when exigencies so compel. The claims of commerce in regard to aerial transportation have not attained the level which were demanded by military considerations. But if we can satisfy the one there is no reason to suppose we cannot meet the latter when the moment arises, possessed as we are of the men who are masters of craft and direction of applied knowledge and science in this distinctive field where organisation is invested with a peculiar and far-reaching significance.

CHAPTER VI

"Safety First" in the Air

"IS it safe?" This is the inevitable question asked by the timorous when extended the invitation to indulge in a trip through the air. It is a perfectly natural inquiry, and one which is not confined to movement by air, although in this direction it is probably animated by deeper misgivings. But movement by air stands upon a plane by itself, although, probably, equally apprehensive interrogation would attend any suggestion to take a trip under water by submarine.

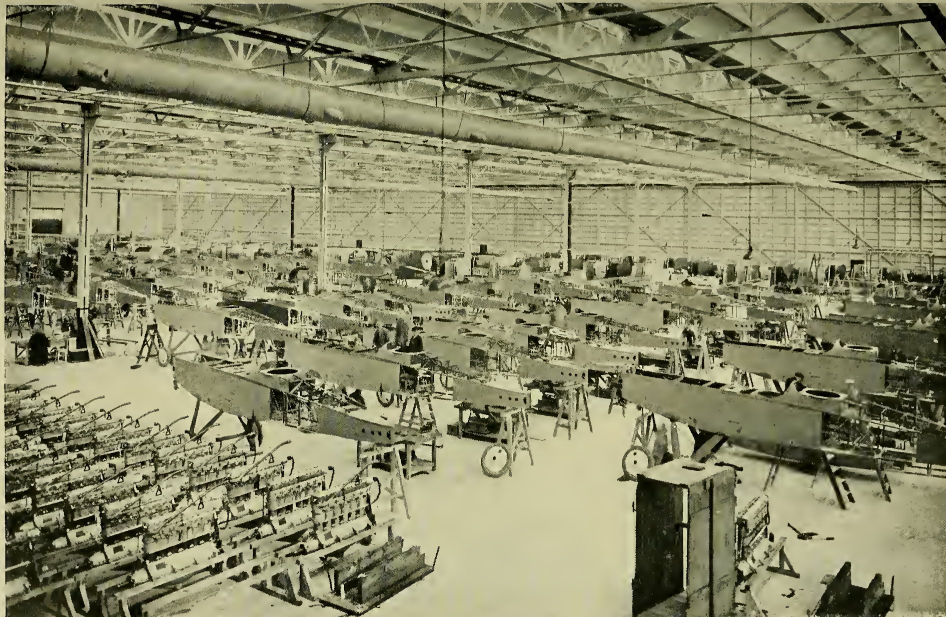
But the air is "something" which few can understand. Imagination does not carry them beyond the one fact which they know full well—it is indispensable to life. They regard it purely as food for the lungs. That space should be transformed into a highway of transportation is somewhat inscrutable, and they reflect upon the slender-looking lines of the aeroplane, although there is lesser trepidation manifested in regard to the airship. To a certain degree this is due to a certain familiarity with the lighter-than-air machine, inasmuch as ballooning has reigned as a sport for over a century, and, what is decidedly striking, has been attended with remarkably few accidents.

The hesitation manifested in regard to the aeroplane is undoubtedly psychological to an advanced degree. The mammoth airship, from its mere dimensions, conveys the impression of safety. The aeroplane seems so puny and

fragile to battle against the forces of Nature—forces which, as everyone knows, are of an extremely destructive character at times. Greater confidence is reposed in the airship from the knowledge that if the worst should come to the worst, and the air should prove triumphant in a battle royal with the handiwork of ambitious man for supremacy, the airship need not necessarily encounter immediate disaster. It possesses the inherent capacity to float for some hours, the sport of the wind it is true, but there is presented the hope, remote though it may appear under certain conditions, of making a safe landing.

With the aeroplane, on the other hand, there is little or nothing to inspire safety. Crashes are frequent; everything hinges upon the faithfulness of a tiny motor. If it goes wrong, or fuel should be exhausted, immediate descent is inevitable. The machine is invested with no innate capacity to hover—to hang on to the air—while the possibility of a repair, if required, being executed during the brief period of descent is too slender to be considered seriously. There is a lack of stability, an absence of tangible support, an invisible factor about the air, which prompt feelings of dubiety. The airman knows that the aeroplane is safe; that should anything go wrong while aloft the chances are a thousand to one that he will make the land below in safety; but it is not easy to communicate these sanguine thoughts to the uninitiated.

One fatal mistake appears to prevail at our popular aerodromes where joy-riding is encouraged. I myself have seen crashed machines left exposed in their tattered and broken condition for days together, to be observed by all who happen to be passing. The airman laughs at the spectacle of torn fabric, splintered wings, crushed undercarriage, and shattered engine. But the man-in-the-street views the wreck in a



BUILDING 100 AEROPLANES A MONTH

The main erecting shop at the Heaton Chapel National Aircraft Factory of Crossley Motors, Limited, which was specially built to increase the output of aeroplanes for the Government, showing the assembling of fuselages. At the bottom left-hand corner are aeromotors ready for installation in the machines.

totally different light. Upon our railways all evidence of a wreck is removed with every possible promptitude. Our shipping companies do not parade the wounds inflicted upon a ship after an inadvertent embrace with another vessel, or the wicked fangs of a rocky barrier. No effort is spared to conceal the injuries from view. Those who are responsible for the maintenance of travel and transportation by rail and sea have learned the wisdom of doing everything possible to prevent the perils incidental to these systems of movement being brought home to their patrons. A similar practice should be embraced in regard to the vessels of the air. A crashed aeroplane should be hauled behind closed doors of a hangar, covered or reduced to scrap and the junk heap with all speed. Its depressing effect is not confined to potential passengers along the aerial highway of joy-riders. The commercial man contemplating dispatch of goods by air is suddenly confronted with the fact that they are likely to suffer injury during transit, to his financial and trading detriment; while recommendations that mails should be carried by air are likely to be received with vehement hostility by those who consider that the safety and positive delivery of their communications must not be jeopardised by any accident en route.

"Safety First" is as imperative in the air as in every other sphere of endeavour. If anything, it is of accentuated significance, particularly during the contemporary period of education and enlightenment. Designers and constructors have appreciated this salient fact, and are unstinting in their endeavours to do all that human ingenuity can suggest to reduce the liability of accident through any inherent fault of the machine. The enterprising pioneers of progress are emphasising the "factor of safety," although it is a moot

point whether the average lay mind really understands the meaning of the term. The intimation that an aeroplane, as, for instance, the Vickers Vimy transport machine, has a factor of safety of five, in the light of existing slender familiarity with technical knowledge, does not convey the intimation that the machine is really built five times as strongly as is necessary to perform the designed duty, or, expressed in other words, that every part of the machine is capable of sustaining at least five times the strain which it ever will be called upon to bear before it will break.

The designer plots, and the constructor carries into effect. To appreciate the significance of the lengths to which the builder is prepared to proceed to ensure the quality of his product it is necessary to pass behind the scenes, as it were, of the big factory. Certain and rigid specifications or standards have been laid down with which materials must comply, but the enterprising manufacturer is not content to shelter himself behind this protection. Matters pertaining to the problem of the conquest of the air are in a state of flux, while knowledge of the materials used, and their behaviour under all and varying conditions, is decidedly meagre and imperfect. Accordingly we find the laboratory dominating the factory in which aeroplane construction is conducted, and the verdict given within these privileged walls decides the final issue.

This is certainly the case at Heaton Chapel, the constructional work incidental to which is described in detail in the preceding chapter. The laboratory or, perhaps, to describe it more accurately, the testing department, is equipped with the latest devices for testing all the materials entering into the fabrication of the modern heavier-than-air flying machine —wood, metal, fabric, glue and so forth.

We all know that ash is an exceedingly strong wood, that it possesses marked flexibility, and that it has been freely advocated as a first-class timber for aeroplane construction. But during the war period the supplies of this timber forthcoming were by no means adequate to satisfy the demand. To meet the deficiency it was decided to press Oregon pine into service. This wood is extensively used in shipbuilding, particularly for masts and spars. It is strong, has a straight grain, and is strikingly free from knots. But there is one peculiarity concerning this timber. During the summer the growth forms thick layers of the sapwood or pith between the concentric rings forming the grain, the last-named thus being spaced somewhat widely apart. On the other hand, with the winter or spring growth, this pith is narrower, bringing the grain, which is finer, much closer.

The pith is soft and, to a certain degree, resilient, being readily broken with the finger nail, but the grain itself is exceedingly dense and hard, a sharp pocket-knife failing to make any impression upon a sound piece of wood which has been well seasoned or conditioned. Accordingly it was decreed that only the winter wood should be utilised for essential parts of the aeroplane where the maximum of strength was desired, and it was conceded to rank second to ash.

But the technical mind is ever investigating. Therefore, at this factory, the experimental testing plant decides to make some individual tests to discover the relative values of the summer and spring growths of Oregon pine. Small sections of wood are taken, preferably pieces about four inches in length by about two inches in diameter. These specimens are shaved down near the centre, evenly on all four sides, leaving the middle portion an inch long by one inch wide and one inch deep. In this way a cubic inch, the unit, is obtained.

This is placed in the testing machine, which is then set in operation. Gradually the two jaws close together, and in so doing exert increasing pressure or crushing effect upon the specimen set between them. This pressure is exercised perpendicularly in regard to the wood, that is, in the line of the grain, and is continued until the specimen collapses, the pressure at which failure occurs being recorded.

The degree of pressure to which the Oregon pine specimens stood up before collapsing was somewhat illuminating. At the same time the resistance offered by the summer growth, which was declared to lack strength, was also striking. I was shown certain specimens where the cubic inch of softer wood had resisted over 5,000 lb.—nearly 2½ tons. But this was not all. Sections of ash, the pre-eminently suitable wood for aeroplane construction, were similarly tested to yield comparative results, and it was somewhat curious to remark that some of these specimens collapsed below the 5,000-lb. mark, and that, although accepted as stronger than Oregon pine, either winter or summer growth, it was even weaker than the summer-grown pine—the lowest in the scale. Of course, the sum of these experiments is not adequate to prove that the confidence reposed in ash is misplaced. Far from it. At another laboratory diametrically opposite results may be recorded, but the experiments in question certainly do prove that our knowledge respecting the strength of timber is far from being complete, and that there is scope for us to modify many conclusions regarding the suitability of this or that wood for the building of aeroplanes.

As a matter of fact, our knowledge concerning materials in relation to aero-dynamics is decidedly hazy. This is inevitable. Flying, especially in so far as the heavier-than-air machine is concerned, is still only in its infancy. It has not

COPPER DEPOSITING PLANT FOR WATER-JACKETS OF BEARDMORE AEROMOTORS

The elaborate plant laid down by Crossley Motors, Limited, to build the jackets by electric deposition of copper.

AEROPLANE-BUILDING AT THE CROSSLEY MOTOR WORKS

All metal parts are joined by means of the oxy-acetylene blow-pipe, in the use of which girls are remarkably proficient.

been harnessed for a sufficient length of time to the laboratory or even to practical application to enable any empirical laws and formulæ to be established. The enterprising aeroplane builder takes nothing for granted. For instance, at the factory in question, the materials were subjected to official inspection and test, and those which complied with the requirements were accepted. The onus was on the authorities, but the gentleman at the helm instructed frequent individual tests to be carried out and the results observed, not to offer conflict with the official decisions but to satisfy himself that the work was being carried out in accordance with the high standard of quality and perfection which he had laid down, and, incidentally, to provide him with valuable material to assist in his post-bellum industrial activity. The records of the experimental testing plant at Heaton Chapel are copious, but they are invaluable to the technical staff, and will assist very materially in the determination of critical factors associated with normal manufacturing operations.

When the aeroplane is in flight it is "alive." No matter how steady the hand which is guiding it, how sensitive the control, it is like the rowing boat upon the placid sea. Air currents and other forces are responsible for this movement, which is not only of a vibratory character, the last-named being primarily due to the motor. Consequently, every member is at work the whole time. We know but little concerning either the magnitude or character of these constant and ever-varying compression and tension strains, or what cumulative effect they exert upon the machine as a whole. And being ignorant, it is our duty to find out; to go in pursuit of knowledge, the acquisition of more and more of which must contribute to greater perfection in construction.

While we cannot accurately determine the extent of the

varying pressures upon wood, wires, and fabric while in the air, we certainly can learn something about the behaviour of wood through the experimental testing plant. At Heaton Chapel I saw another interesting machine at work upon a short length of wood—perhaps thirty inches long by one inch square. As received from the woodworker, who had reduced the piece selected by the tester to the required dimensions, it was thrust into the machine. It rested in two loops a few inches from the respective ends, while near the centre were two other loops attached to a lower member of the machine, working upwards and downwards upon a vertical screw.

The machine was set in motion. Slowly, almost imperceptibly, the central arm descended, and in so doing pulled down the specimen of wood. The latter commenced to assume a bow shape, which increased as the arm continued its inexorable descent. When the bow form became magnified, an ominous cracking was heard. The wood was feeling the full effect of the pressure brought to bear upon it, and was perilously approaching the point at which it would have to give way. Suddenly there was a report of rending and splitting, and the fibres of the wood of the lower surface flew out. The stick had collapsed under the strain. The machine was stopped, the record of pressure was taken, together with the degree of deflection, and the pressure removed. The stick was taken out and examined.

To the uninitiated such work may seem a waste of time. But what does it show? The piece of wood was supported only by the loops near the ends through which it was passed, while the central loops pulled it vertically downwards. Imagine this specimen to be part of an aeroplane, and the air to be taking the place of the descending screw-fed member. When a machine is travelling at high speed through the air,

and possibly against a heavy head wind, the pressure exerted by the air notches a considerable figure, so that it is not so absurd as it may seem to replace an invisible deflecting force by a mechanical force. In the testing machine the under side of the piece of wood is being subjected to tension; its fibres are being stretched to the utmost of their elasticity, and that limit will be revealed in pounds per square inch. On the other hand, the upper surface is being submitted to compression, because its fibres are being pressed inwards in respect of their length. Similar tension and compression stresses are exerted upon every part of the aeroplane while it is in flight—wood, metal, wires, and fabric. It is the testing machine which has revealed much information concerning these two forces and their effects, about which our knowledge formerly was far from being sound.

With this apparatus, it is also possible to test and determine the strength of actual component parts. For instance, a rib can be submitted to the ordeal. When the lever commences to exert its downward pull, which coincides with that of gravity, the tester can follow and measure the result of the forces and the general behaviour of the rib during the operation. Similarly, sections of the laminated spars can be tested, and a check thus instituted, not only upon the work of gluing and pressing the layers together, but upon the adhesive properties of the glue itself. In fact, there is no section of the projected machine in being which cannot be tried in this manner, and the work not only assists in the actual construction of the machine, but reacts in the other direction—that is, back to the drawing office, since the results of tests provide material for the designer in the elaboration of his calculations.

Metal work is also passed through its variety of tests. One machine is capable of reproducing the shocks and jars similar

to those experienced, for instance, in landing. A pin or bolt, such as is employed for securing the wings to the fuselage, can be taken and made fast in the jaws of the machine. To the end of a swinging rod is attached a ball of known weight. When quiescent, this rod and ball recall the familiar plumb line—they hang vertically. The pin or bolt to be tested is set in the jaws in such a way as to allow the ball to strike it, and to receive the full force of the blow. Above the machine is mounted a quadrant, the lever or recording hand moving over which is connected to the swinging weight. It is graduated, each calibration having a certain value. From the lower side of the machine projects a curved arm serving as a guide to the ball in its descent to assure movement through the vertical plane, and which is also furnished with a movable stop regulating the lift of the ball.

The ball, resembling a pendulum, is moved a certain distance along its guide and then released. It swings down to strike the piece of metal which is fixed in the jaws a blow. Only a single blow is struck, and the arrangement is such that it is given fairly and squarely, and without rebound. The force of the blow or impact varies according to the height to which the ball is lifted and released. If moved only an inch or thereabouts, the resultant blow will be an almost indistinguishable tap, while, on the other hand, if lifted to the full limit of its travel, the ensuing thwack will be decidedly substantial. The pendulum is simply released; no impetus is imparted to it, so that its descent is really gravitational. By consulting the calibrated scale fitted to the top of the instrument, the operator can determine the force of the blow in pounds.

The effects of the pounding thus administered are interesting to examine. A specimen cut from a rod of raw

material, or a manufactured part, may snap like a carrot, and under a single blow. On the other hand, it may bend or break in a splintered form. It all depends upon the character of the metal. The tests are interesting for the reason that the break sometimes occurs at the most unexpected point, thereby revealing a latent flaw in the metal, or that the working of the piece has been carried to too fine a point. As a rule the tests are conducted to destruction because, thereby, the technical mind not only learns whether or not the collapse occurs at the predetermined limit—thus establishing or upsetting calculations, but also ascertains precisely how much in excess of the anticipated strain, if any, the test piece withstands before collapse.

No material entering into the building of the aeroplane escapes its test. This not only acts as a check upon the material and its manufactures, but serves to reassure the aeroplane builder that he is pursuing the correct lines; that his product is of the highest quality within the compass of human ingenuity, and that he is rendering the vehicle as safe and secure in its varied details as is within range of his producing capacity, by acting as a check upon the quality of the workmanship of his employees. The largest machine in the Crossley works is capable of applying tests up to twenty tons per square inch, which is far in excess of what any single part of an aeroplane is likely to be called upon to withstand when in service—that is, if handled with reasonable skill.

At the Heaton Chapel works, the rule concerning the examination and testing of materials utilised in the construction of the machines for the airmen is extremely rigid. And the fact that the tests are repetitive, conducted at all and every stage, many of a "surprise" nature from completed work, has contributed to the high standard of manufacturing ex-

cellence which was established in the first instance. A reputation for super-excellence is not built up in a day; it is the carefully compiled assembled fabric of years. In so far as the Crossley organisation is concerned, it had established a level of super-quality in other fields of productivity—the gas-engine and the motor-car, and naturally it was expected that this standard of excellence should be manifested in connection with the building of aeroplanes. This in itself is a measure of protection to the airman; is sufficient to instil a peculiar confidence. He knows the manufacturers will not let him down. It also serves to ensure the preservation of the quality of the raw material utilised. It is the inexorability of the experimental testing department, and the knowledge that it will ruthlessly expose any hurried or indifferently executed work, which enables a high, all-round standard of excellence to be maintained, and which has contributed to the manifestation of a peculiar and distinctive feeling of security and safety in the air, appealing as much to the man at the wheel, who carries heavy responsibilities upon his shoulders in the form of human life and limb, as to the passengers.

There is one particular in which invaluable assistance has been extended by the authorities. At the official factory identified with the Royal Air Force, the standardisation of general supplies or accessories was carried to complete success. This standardisation of the small details, such as turnbuckles, nuts, and bolts—accessories which, in 1914, were of infinite variety, as well as difficult of acquisition in this country—eased the task of the aeroplane constructor very materially. Chaos and confusion of British and metric measurement were resolved into method and system. This also applied to many of the materials, in the production of which the manufacturers were compelled to conform. For

instance, the glues have to comply with a certain specification, as do also dopes and varnishes. Linen also has to be woven according to a standard, while wires and other incidentals are governed by some rigid rule or regulation. In this way the aeroplane builder has been relieved of many anxieties, although, in a factory such as I have described, rigid tests are conducted at every turn. They are independent, and conducted more elaborately than is possible to the authorities.

This is as it should be. Aerial navigation has reached a precarious stage. Its future success depends essentially upon the appeal it makes to the general public, whether it be in the movement of passengers or freight. Both the ordinary traveller and commerce are in a hesitant mood. Extend uncompromising evidence that the aerial highway is as safe as road, rail, or sea, and it will be promptly accepted. And in this task of education everything must be subservient to "Safety First."

CHAPTER VII

Some British Aeromotors of To-Day

WHILE the design and manufacture of the inert body of the aeroplane has undergone striking perfection during the past few years, this work has been confined to minor details. Substantially the machine itself is the same now as it was ten years ago. The one field in which real and far-reaching development has been recorded is in connection with the motor. This is the field in which the stress and exigencies of war exerted their most beneficial influence, because, in 1914, the engine constituted the weakest and most unreliable part of the whole. The concentration of thought and ingenuity upon this factor of propulsion brought about many revolutions in ideas and practice, and has contributed to the attainment of a remarkable degree of excellence and reliability, enabling the aviator to speed through the air at incredible velocities; far in excess of those reached by birds and insects, whose home is the air, and to reach altitudes which, a decade ago, appeared to be utterly beyond the reach of man. One has only to compare the aeromotor of to-day with that of 1910 to grasp the immense forward strides which have been made. The former bears as much resemblance to the latter, no matter from what point of view it may be regarded, as does the contemporary express railway locomotive to the *Rocket*.

As is well known, the type of prime-mover which has been universally adopted for the propulsion of the flying-

machine, both aeroplane and airship, is the high-speed explosion motor, which brought about such a revolution in highway locomotion. The extension of the field of application for this engine from the highways and also seaways to the airways was logical, inasmuch as its conquests upon the land and water were a happy augury of success in the third field. The highest speeds recorded upon land, sea, and in the air have been attained by the aid of this engine. These wonderful achievements, in the three realms of travel, have been possible for the simple reason that this type of internal combustion engine presents the engineer with a source of energy attainable in high powers for really insignificant weights, a combination which, at the moment, has not been approached by any other type of prime-mover. Moreover, it possesses the additional advantage of being compact for the power developed, occupies relatively little space, and is easy and simple to handle or control.

It has been developed essentially from the motor-car engine. Previous to the coming of aviation, engineers were striving to equip motor-cars—even boats—with engines of increasing powers, and were sparing no effort to reduce the weight factor in the consummation of their ambitions. Racing machines were fitted with engines which needed but little modification to fit them for application to the air, especially for the propulsion of the airship. Consequently, it is not surprising to learn that the latest achievement in motor-engine design, as applied to racing cars, constituted the real starting point for aerial development.

It is only right to mention that this movement did not synchronise with the outbreak of war and its consequent demand for aeroplanes. It had already commenced many years previously, but was pursued rather along erroneous and ding-

dong lines. Some of the pioneers sought to achieve their end by departing from accepted design and practice, devising weird motors which, while proving light in weight, failed to stand up to the rigours of work in the air. Either these pioneers were not content to accept the motor-car model as the starting point or standard for evolution, or they preferred to give full rein to their inventive brilliancy in the hope that they might eventually succeed in producing quite a different type of motor, and one essentially adapted to the air.

Some of the pre-war departures in designs have survived, notably the radial, rotary and V types. Others were directly born of the war. The radial and rotary engines represent quite a reversal of conventional practice. Instead of the cylinders being set in a line along the crank-shaft they are disposed radially, like the spokes of a wheel. In the radial engine the cylinders are stationary, while in the rotary motor they revolve round the crank shaft. The Anzani is a typical example of the first or radial system, while the Gnôme, Le Rhône, and Bentley motors are common expressions of the second or rotary principle. The rotary engine, while it has proved satisfactory for certain types of military aeroplanes, is scarcely likely to meet with widespread favour in the commercial field, although, during the opening stages of the new movement, they may have a certain vogue to absorb the stocks thereof which are available.

These types of engine suffer under certain disabilities which, while of minor significance in military duty, are of far-reaching significance to commercial application. They are heavy in consumption of petrol and lubricating oil, are susceptible to ready derangement, requiring frequent overhaul owing to their construction being carried out along very light lines, while they offer higher head resistance than the

other types. Another shortcoming is the inability to produce them in relatively high-powered units. On the other hand, they have certain advantages. Being air cooled, the attendant gear constituting the water-cooling circulating system, including pump and radiator, as well as the water itself incidental to the quasi-motor-car engine, are eliminated. So an appreciable saving in weight is obtained. The principle of design also admits a lower weight per horse-power to be secured. But when advantages and disadvantages are carefully weighed, the former are not adequate to discount the latter. Consequently, both the radial and rotary motors will probably be retired into oblivion or attain only extremely limited application. As a matter of fact, it is doubtful whether the rotary engine would have survived to this day had it not been for the war, which, stimulating ingenuity, enabled certain improvements to be effected, rendering the motor suitable for specific, though severely limited, military services.

The "V," or Vee type, as it is more colloquially called, does not represent such a wide departure from motor-car practice. Indeed, this model made its appearance in one or two pre-war car models. The cylinders are stationary and set in line, but in two rows, upon a common crank shaft, at an angle of 60 to 90 degrees to one another—30 to 45 degrees on either side of the vertical. This allows twice the number of cylinders of given dimensions to be disposed in the same longitudinal space as would be required for a vertical engine of half the number of cylinders. Thus, instead of four or six cylinders of the latter, we are able to get eight or twelve of the former, each opposite pair of cylinders being connected to a single crank pin. The Vee type has met with pronounced favour, although it offers more head resistance than the vertical type, but its efficiency is so much

higher. The Hispano-Suiza, R.A.F. or "Raf," Renault, Rolls-Royce, and Sunbeam-Coatalen are probably the most notable and efficient motors following this cylinder arrangement. The vertical system is a direct application of conventional motor-car engine practice to the aeroplane. So far as this country is concerned, it has not been very extensively practised, although it stands high in favour in the United States. The Beardmore is the outstanding British expression of the idea.

The most recent development is the Double Vee arrangement. In this instance the cylinders are set in three rows, somewhat after the manner of the letter W or "VV"—hence the name—the central row being vertical and flanked on either side by a corresponding line of cylinders set at an angle of 40 degrees from the vertical. By this arrangement it is possible to accommodate an engine of eighteen cylinders in the same length of space as would be required for a vertical motor of six cylinders. The Napier engine follows this arrangement, and it has proved eminently satisfactory. The Vee, Double Vee, and vertical motors are water cooled, and although the introduction of the water-radiating system undoubtedly increases the weight per horse-power appreciably, this disadvantage is more than offset by the enhanced efficiency obtained, while the fuel and oil consumption is relatively low for the power developed. Engine speeds range from 1,250 to 2,100 revolutions per minute. In those instances where the revolutions are high, a reduction gear is introduced to reduce the propeller speed. Direct transmission at these speeds would be impracticable, and would lead to loss of propeller efficiency for the reason I have previously explained.

While a variety of British engines were designed and

built to meet the requirements of war, many will not be commercialised, at least, not at the moment, although, of course, so long as stocks are available, they will doubtless be used to a greater or lesser degree. Detailed description of all these engines would require more space than is available, so I will confine myself to narrating the outstanding features of those motors typical of British designing and constructional ingenuity with which, for the time being, we are possibly more familiar.

The Beardmore Aeromotor

This engine, as already stated, belongs to the vertical classification, and arouses attention from the excellence of its design and workmanship manifested in its construction, while there are one or two features which are of more than passing interest. The 160-190 horse-power model has six separate cylinders of 142 millimetres bore by 175 millimetres stroke, and the 174 brake-horse-power is developed at normal speed—namely, 1,250 revolutions per minute. Weights have been reduced wherever possible by the utilisation of special metals, while the water-jackets, instead of being cast with the cylinders, as is usual, are distinct and built up by electro deposition of the copper, the process being broadly analogous to that followed in silver-electro plating. In this manner it is possible to secure a very pronounced saving in weight as well as a high degree of strength, the copper jacket being extremely thin, yet sufficiently stout to withstand the rough wear and hard usage incidental to aeroplane service.

The valves are placed on top of each cylinder, and are automatically operated by a rocking arm, one arm serving both inlet and exhaust valves, the former being placed on one side and the latter upon the other side of the cylinder head. The tappets operating the valves are mounted at the

extremities of the rocking arm, which is connected upon the inlet side, to a vertical rod which extends downwards to engage with the camshaft. Thus the valves are mechanically operated in accordance with the universal aeroplane practice. The sparking-plugs are of the three-point type, extensive trial having demonstrated their superiority to the conventional two-point plug, while two plugs are fitted to each cylinder—on either side along the longitudinal line—for purposes of accessibility. Two carburetters are fitted to the engine, and are set on the inlet side, but they are coupled together to work in synchrony, and feed into a common water-jacketed inlet pipe, whereby the gas is led and distributed to the six cylinders.

Ignition is by the high-tension magneto, and two separate magnetos are fitted. They are quite independent of each other, one being a plain, high-tension magneto, and the other a starting magneto. The latter combines a normal second magneto ignition for the motor, and, in addition, a hand-starting magneto is provided. The two magnetos are synchronised accurately, the maximum current generated by each flowing to the plug in the respective circuit, while the break in each occurs at the same instant.

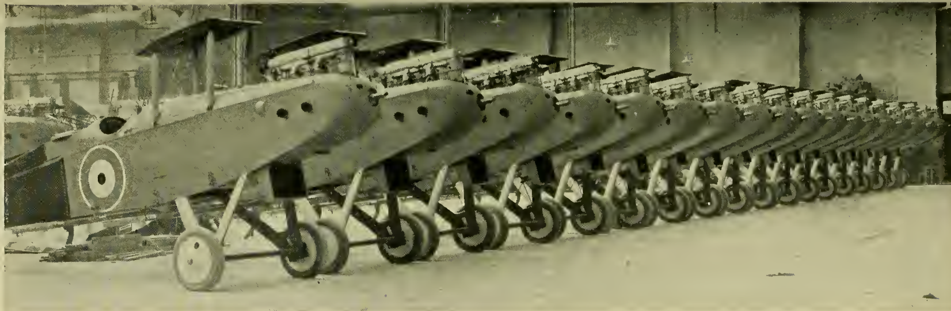
Another outstanding feature of this engine, and one which conduces to a saving in weight, is offered by the pistons. These are made of a specially tough steel, enabling the wall of the piston to be reduced to $\frac{1}{25}$-inch in thickness. Being about as thick as a stout sheet of paper, extraordinary lightness is secured; but, at the same time, although exceedingly tough steel is employed, care must be manifested in handling the piston when the occasion arises to dismantle the engine, otherwise its dead circular shape is likely to suffer deformation. This, however, is readily remediable in the hands of a

skilled mechanic without impairing the strength or true working of the piston in any way. Similar care, obviously, must be displayed in connection with the jacket, which, being of copper, and likewise extremely thin, is likely to suffer injury through careless or unskilled handling. Copper, as is well known, is very ductile, and, owing to the electric deposition system followed, the jacket is composed of the pure metal, without any alloy which might serve to stiffen it.

By reason of the ingenuity manifested in the design and fabrication of this motor, the total weight of the engine has been brought down to 620 lb. in the dry condition—3.56 lb. per brake-horse-power. The petrol consumption is 96 pints per hour, or .55 pint per brake-horse-power, and should not exceed .63 pint. Should it do so, an investigation is usually conducted to ascertain the reason, which is probably found to be due to some minor mishap in the ignition or carburetter system, or to a leakage, any one of which, however, is capable of ready rectification. The lubricating oil consumption is 5 pints per hour.

Travelling in the air differs widely from travelling along the high road in a motor-car. Under the first-named and normal conditions the engine is always working at full load, which is maintained in the same way as the engines of a trans-Atlantic liner, after once the open sea is reached, are kept at one speed throughout the journey, only undergoing modification to meet an emergency. In the air the Beardmore engine should not be run at more than 1,400 revolutions, in any circumstances, though the most efficient results will be achieved at 1,250 revolutions. If these conditions are fulfilled, a thorough examination of the engine should be made after 150 hours' run, and complete dismantling and overhaul conducted at the end of 300 hours.

The Beardmore engine made its bow in 1911, and aroused attention during September of that year by establishing a new world's record for altitude. During the following month —October—it set up eight new records, three for speed, two for distance—250 kilometres, or 156¼ miles, with pilot and one passenger—and three for time, the best being two hours with pilot and passenger. During the year 1912 it created successive new records in regard to height, and also for vertical or climbing speed, while in October, 1913, it carried off the honours for duration of flight, with pilot and seven passengers, as well as three height records. This was the engine with which that indefatigable pioneer of the big aeroplane, Colonel S. F. Cody, gained the highest awards at the British Military Reliability Trials in August, 1912, against twenty-four aëroplanes representing ten different makes of engines—the pick of British, French, and German design. The motor fitted to this machine was of 120 horse-power. The Martinsyde monoplane, a standard two-seater, which secured second prize in the second aerial Derby, held in 1913, was also equipped with a 120 horse-power standard Beardmore aeromotor, and covered the course of approximately ninety-five miles at an average speed exceeding seventy-two miles per hour. It was with his biplane, driven by an engine of this type, which had been almost in everyday use for more than a year, that Colonel S. F. Cody won the £4,000 prize in the International section, and the first prize of £1,000 in the British section—£5,000 in all—in the aeroplane trials held by the British Government in 1912. Its record during the war was equally satisfactory, the consistent steady running and reliability of the engine constituting its most conspicuous features.



(1) AEROPLANE BUILDING: COMPLETED MACHINES READY FOR DISPATCH. (2) THE FIRST CROSSLEY-BUILT AEROPLANE

Some British Aeromotors of To-Day

The Napier-Lion Aeromotor

About the time the Armistice was signed, a new British aeromotor made its appearance, the design and construction of which aroused widespread attention. This is the Napier-Lion. While it did not emerge from the searching tests and exacting trials to which it was submitted in time to demonstrate its possibilities under actual war conditions, it was at once put through its paces in other directions, in which its performance was somewhat sensational. From its behaviour, it would seem as though this engine will have a distinct future in commercial operations.

This aeromotor, designed and built by the firm identified with the construction of the Napier motor-car, is of 450 horse-power. It belongs to the Double Vee class, the twelve cylinders being set in three rows, or blocks of four each. The cylinders have a bore of 5½ inches, while the stroke is 5⅛ inches, the short stroke principle thus being embodied.

In many essential details the engine differs markedly from prevailing practice, which give it a distinct individuality. The cylinders follow the monobloc system, although each cylinder is separately water-jacketed to ensure the maximum thermal efficiency at all altitudes. The cylinders are made from steel forgings, and the water-jackets are of thin steel, pressed to required shape from the sheet and vertically welded together, while they are held in position by being welded to flanges on the cylinders. The arrangement is such that the water space around the cylinder tapers slightly from top to bottom. Another departure from accepted aeromotor design is that the cylinder heads, instead of being separate, are cast in one block for the four cylinders forming the row, and this one piece is bolted down. This arrangement has many distinct

advantages, since by its removal access is instantly offered to the interior of the four cylinders and pistons, while the sixteen valves being carried in the single head are likewise easy of access. To save weight, this monobloc cylinder head-casting is made of aluminium. It also carries the camshafts, which act directly on the valve heads. Each cylinder is provided with four valves—two inlet and two exhaust respectively. The pistons, cast from a specific aluminium alloy, secure the maximum of strength with the minimum of weight.

The carburettors are set low at one end of the engine, and are provided with separate air intake pipes, the object of this arrangement being to eliminate the risk of the machine catching fire. As there are three separate air intakes, a possible back-fire in one cylinder cannot bring the whole engine to a stop for the simple reason that, if one block should fire back in this way, the other two blocks will keep the engine running and thus draw in the flame. In so far as the heating of the carburettor is concerned, a somewhat unusual practice has been followed. The water-jackets are carried right down to and round the throttle barrels themselves. This arrangement reduces the risk of the carburettors freezing at low temperatures, such as are encountered in extremely high altitudes. The elimination of this danger is of far greater significance than may possibly be imagined, but to emphasise the character of this liability, it may be mentioned that on the occasion of one test to which this engine was subjected a temperature of −31 degrees Fahrenheit was reached. Two 12-cylinder magnetos are fitted.

The crank shaft is mounted on roller bearings. It is four-throw, the connecting rods of three cylinders, those in each transverse line, being mounted upon one web. Owing to the special lines of design followed in regard to the crank shaft,

the reduction gear runs very smoothly, the gearing being disposed with the propeller shaft over the crank shaft. This permits a propeller of the largest possible diameter to be fitted, enabling the highest possible efficiency to be obtained and the power of the engine to be fully utilised. Great attention has been devoted to details concerning lubrication. This is entirely automatic, and special arrangements have been incorporated to prevent the manifestation of the evils attending excessive lubrication under adverse conditions, as, for instance, when the aeroplane is carrying out a long precipitous dive, or is making a sustained steep climb.

While the general arrangement of the engine may be gathered from the illustration opposite p. 128, this fails to bring home in a convincing manner the small size of the actual engine. In so far as the work of elaborating and building an aeromotor is concerned, the engineer is compelled to remember that his creation must offer the minimum head resistance. To achieve this end satisfactorily he must compress the utmost power within the very smallest space. These requirements are fully satisfied in the Napier-Lion engine, while it is also extremely light—another important factor. Weight has been brought down to 1.85 lb. per brake-horse-power at normal power, which includes the reduction gear; while it is approximately 2.5 lb. per brake-horse-power in running order with water in the jackets. The motor is economical in petrol and oil consumption, the former being about ½-pint per brake-horse-power-hour, while the latter is approximately 9 pints per hour for the whole engine.

Although this aeromotor is light, the result of the general principle of design which has been followed, it is of rigid construction, compact, and runs with striking smoothness.

The high standard of reliability which it has attained is due essentially to this smooth running, the special design evolved having permitted individual parts to be made thoroughly substantial, and yet giving a very low weight for the whole engine. One feature that cannot fail to impress even the lay mind is the difficulty in determining from mere observation whether the engine is running or not. This is due to the circumstance that the whole of the moving parts are so completely enclosed.

Although this aeromotor was denied the opportunity to prove its worth under Service conditions, it speedily established its capabilities by setting up a new record for altitude. On January 2, 1919, Captain Lang, R.A.F., a well-known Australian motorist and explorer, accompanied by Lieutenant Blowes as observer, set out from Martlesham, near Ipswich, in an Airco two-seater biplane, fitted with the Napier-Lion 450 horse-power aeromotor. This was practically the first public flight ever attempted with this engine, so that it virtually represented an experimental venture, although, of course, the results of the many severe tests through which it had been passed were known in privileged circles.

Leaving the ground in a 35-mile wind, Captain Lang at once set the machine on a steep ascensional course, firmly resolved to establish a record for altitude if at all possible, and thus realising an ambition which twice previously had been denied him. It was no mean task to essay, seeing that it involved climbing to an altitude exceeding 25,800 feet, which was that attained by an Italian pilot in 1916, who by his achievement lowered the record set up by Lieutenant Oelrich in 1914, who reached 25,750 feet. But the Italian record was completely vanquished, because Captain Lang, according to the barograph record, climbed to a height of

30,500 feet (nearly six miles), a matter of 4,700 feet in excess of the Italian effort. But the daring pilot not only carried off the record in regard to altitude, but established a new one in point of time occupied in the ascent, inasmuch as the foregoing level was reached in 66 minutes 15 seconds, as compared with the 117 minutes occupied by the Italian aviator in climbing to 25,800 feet. Indeed, the rapidity with which the ascent was made was not the least remarkable feature of the daring undertaking, which offers striking testimony to the capabilities of the Napier-Lion aeromotor. The 25,000 feet level—only 800 feet below the Italian feat—was actually reached in the short period of 38 minutes 20 seconds. Thus the last lap of a little more than a mile occupied almost as much time as making the first five miles, due to the extreme rarefaction of the atmosphere, and this fact serves to bring home the important part which decreased density of the air plays in dynamic flight.

The daring journey was not free from thrill and excitement. At 20,000 feet the mercury in the thermometer had sunk so low as to register 31½ degrees of frost. At this point, owing to the difficulty experienced in breathing, Lieutenant Blowes was compelled to resort to the oxygen supply, which had been placed on board in a compressed form in cylinders. But vibration had broken the pipe connection with the cylinder, rendering it useless. He endeavoured to attract the attention of his companion at the wheel, but collapsed before he could pass the note which he had written to Captain Lang, who, unaware of the mishap to his observer, continued his upward journey. At 28,000 feet the pilot found his heating apparatus was not working efficiently; while at 29,000 feet he, too, commenced to suffer distress from the rarefied air. However, he stuck to the wheel and kept the aeroplane at the

climbing angle until he notched the 30,500 feet. Doubtless he would have continued his upward journey, but the limit of mechanical endurance had now been attained. There was insufficient air pressure to maintain the petrol feed to the engine. The joy-stick was pushed over, the nose of the machine was depressed, and the descent was commenced, being carried out slowly, so that the strain upon the physical systems of the aviators might not be unduly accentuated, although the pilot was still ignorant of the fact that his observer was unconscious. At 10,000 feet, however, Lieutenant Blowes "came to." Upon reaching the ground both aviators were found to be suffering severely from the ordeal, which is not surprising, bearing in mind the terrific extremes to which their physical systems had been exposed within a brief period. The observer had to proceed to hospital to receive treatment, especially to his hand and toes, which were frozen, while the fingers and face of the pilot were also frost-bitten.

Another noteworthy performance recorded by the Napier aeromotor, but in a different field, was the flight in April, 1919, of the Airco aeroplane, driven thereby from Madrid to Seville and back. The round journey of 500 miles was covered in 265 minutes, flying time—an average of 111·3 miles an hour, or nearly two miles a minute. The outward flight was made in 130 minutes, while the return journey was covered in 135 minutes. On May 5, 1919, this same aeroplane, which was in regular aerial service in Spain, flew from Madrid to Barcelona, approximately 300 miles, in 150 minutes. That the Napier aeromotor coincides with exacting Service requirements was shown convincingly upon another occasion, when, with full military load, it attained a speed of 140 miles an hour at an altitude of 10,000 feet.

Some British Aeromotors of To-Day

The Rolls-Royce Aeromotor

One of the most familiar aeromotors to the community at large is undoubtedly the Rolls-Royce. Some idea of the part which it played, and was destined to play, in order to maintain our supremacy in the air during the war, may be gathered from a few facts. Up to the signing of the Armistice, on November 11, 1918, of 122 Handley-Page bombing machines supplied to the Royal Air Force, 113 were fitted with this aeromotor; while of 1,524 completed Bristol Fighters which had been delivered to the authorities, no fewer than 1,364 were driven by Rolls-Royce engines. On Armistice Day the engines of this design in the possession of the British forces exceeded 1,000,000 horse-power.

This aeromotor has been supplied in several powered units, each model having a distinctive name for purposes of ready identification, such as "Eagle," "Condor," and so on, but there is no difference in fundamental design or construction, so that the description of one type applies to the others. For our purposes, therefore, I propose to describe the "Falcon," the 280 horse-power aeromotor, which, it is believed, will be found adequate to meet the varied requirements of commerce, while it also constitutes a convenient unit. Of course, should commercial flying develop, there is no reason to doubt that more powerful units will be designed, but this is a matter for future decision.

The engine is of the Vee water-cooled type, having twelve cylinders set in two rows at an angle of 60 degrees. The mechanical balance and turning movement are eminently perfect, and these factors, in combination with the ratio of weight to power, render it ideal for the varied exigencies of commerce. The long stroke is favoured, this being 5¾ inches,

the bore is 4 inches, while the 280 normal horse-power is delivered at the normal engine speed of 2,250 revolutions per minute. The cylinders are made entirely of wrought steel, the design of which follows special lines, affording reliable and efficient construction, unmeasured attention having been given to their elaboration, as well as to all incidental gearing and parts, to assure reliability, strength and efficiency for the least weight possible.

The motor is furnished with four carburettors, which are so arranged as to reduce the risk from fire to the absolute minimum. It is impossible for petrol to collect anywhere, internally or externally, in the engine, while the carburettors are so disposed as to drain away from the engine to a point outside the cowling in a manner which experience and knowledge have demonstrated as being the most satisfactory. Ignition is in duplicate, there being two complete and independent magnetos, each of which fires the twelve cylinders.

Ready accessibility is an outstanding feature of the motor, a point which has met with wide appreciation, second, perhaps, to its striking smoothness of running and reliability. The "Falcon" may be said to represent the embodiment of the ideas which experience has already demonstrated as being essential for commercial service. The requirements of peace differ very significantly from those dictated by the exigencies of war. For instance, there is not the necessity to rise to such high altitudes as were imperative under Service conditions. Consequently it was found incumbent to carry out certain modifications in design, such as facilities to allow the full horse-power to be used indefinitely at low altitudes, and to enable the machines to get away with heavy loads of fuel to secure a long radius of action so essential in commercial operations.

Economy and efficiency of performance are the governing factors in the commercial expansion of the aeromotor. There is no sentiment in business. It regards achievement in the cold calculating light of pounds, shillings, and pence. It was so with the railway, with the steamboat, and with the motor lorry, and it will be the same with the aeroplane and airship. Consequently the designer of the aeromotor is called upon to face a condition of affairs and perspective from which he has hitherto been absolved.

Efficiency and economy do not lie wholly with the engine. These factors find their real expression at the propeller. An engine may leave nothing to be desired in point of low cost of running when considered individually, but if all this advantage is lost in propeller delivery it counts for nothing. Consequently fuel per horse-power at the propeller, or propeller-horse-power is the factor which now comes into the situation. To ensure the utmost fuel economy at the propeller it is necessary to have an efficient reduction gear system. The Rolls-Royce reduction gear of 56/95 ratio, giving a normal propeller speed of 1,327 revolutions per minute, is of the epicyclic type, the outstanding advantage of which, particularly in aerial duty, is that no pressure is imposed upon the crank shaft bearings due to reaction of the drive, while the direction of motor is not reversed. Moreover, the gear only has to convert part of the horse-power. The Rolls-Royce system, even under commercial conditions, has already proved highly efficient and economical in fuel, which, coupled with reliability and smooth running, is undoubtedly responsible for its extensive utilisation.

While petrol of the highest grade is essential for the efficient running of the aeromotor, experience has demonstrated that the engine under question gives the most satis-

factory all-round results with a mixed fuel, comprising petrol 80 per cent., and benzole 20 per cent. This composite fuel gives slightly more power than straight petrol, but this is not the only advantage from the commercial point of view. It is less detonating in its combustion, and for this reason will make appeal in view of the relatively low altitudes at which commercial flight will be conducted for the most part. The oil lubricating system is distinctive. The quantity of oil carried in the engine itself is really negligible. Lubrication is carried out upon lines whereby a single oil pump supplies oil under pressure to all the main bearings, while a single scavenger pump removes the oil accumulating in the crank-case to the oil tank. The oil consumption approximates 6 pints per hour. The water circulating system is simple in character, and the quantity of water carried in the water-jackets of the cylinders, pipes, and pump is 2½ gallons.

The engine is provided with a hand-starting gear, which is somewhat reminiscent of the system employed in connection with the motor-car. Cranking is done through a reduction gear, having a 9 to 1 ratio, the induction pipes, of course, being primed with petrol before starting-up is attempted. The engine is then started by means of the hand magneto. Priming of the induction pipes is conducted from the pilot's seat by means of a special device embodying a hand-pump. It can be fixed at any convenient point, while, as the priming charge can be diverted from one set of engines to another through a change-over cock, only one apparatus need be carried for this duty.

It is imperative that the engine speed should not exceed the normal, except in cases of emergency, when short spells, or "bursts," may be found unavoidable. Even then the engine speed should on no account be forced beyond 2,500 revolu-

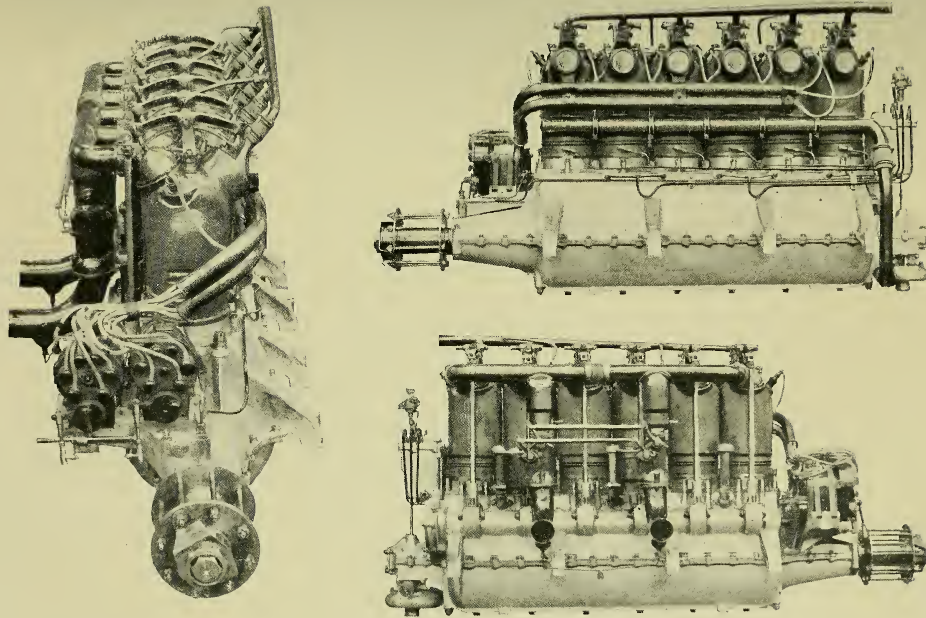
tions per minute. The total weight of the engine, in the dry condition and without reduction gear, is 630 lb., representing 2·25 lb. per horse-power, while with reduction gear it is 686 lb., or 2·45 lb. per horse-power. The aeromotor can be utilised either as a tractor or pusher as desired, while the direction of rotation is anti-clockwise. In completing the design for the "Falcon" engine the creators studied the issue wholly from the commercial standpoint, which demands that a motor for such duty shall be reliable in running, safe, economical, of high consistent performance, durable, and comfortable, producing the minimum of vibration even under maximum speed conditions.

Many of the commercial planes now in service are equipped with this aeromotor, and are giving consistently high service. Up to the time of writing the only two aeroplanes which have flown from England to India were fitted with Rolls-Royce engines; while the engines which were utilised in the aeroplanes delegated to the expeditious conveyance of Ministers, officials and dispatches between London and Paris in connection with the framing of the Peace Treaty were engined with aeromotors of this design.

But undoubtedly the crowning performance standing to the credit of the Rolls-Royce aeroplane motor is in connection with the direct Transatlantic flight of the Vickers-Vimy biplane from Newfoundland to Ireland. Upon this occasion the qualities of endurance and consistent running were emphasised to no mean degree and completely vindicated the superiority of British aeromotor engineering, which possibly underwent a certain degree of criticism as the result of the previous failure when Hawker, in his attempt to complete the flight, was forced to the water after covering half the journey, to be picked up by a passing steamer.

It is questionable whether we really appreciate the immense strain which a flight of this character imposes upon such apparently insignificant mechanism as that of the modern aeromotor. We are disposed to take too much for granted, a feeling which is doubtless due to the knowledge that the machinery with which our modern ocean greyhounds are fitted pursue their uneventful movement after once being started, for days on end. But to compare the contemporary aeromotor with the marine steam engine is scarcely fair. The last-named is the product of decades of sustained study and continuous improvement, which have brought it to a high pitch of perfection, whereas the former is only in its infancy. Furthermore, a justifiable parallel cannot be drawn, because the conditions are so vastly dissimilar. A breakdown on the sea occasions nothing beyond a slight delay or continuance of the journey under reduced speed. A breakdown above the sea—in the air—means a forced descent unless the reduced speed attainable does not fall below that necessary to sustain the machine, when possibly the journey can be continued until succour comes in sight.

The tax imposed upon the aeromotor, which is called upon to work for all it is worth against the collar the whole time it is aloft, is enormous. Some idea of this strain may be gathered from the anticipatory calculations which were made in relation to the flight over the 1,880 miles of the open Atlantic. If the aeroplane, fitted with twin engines such as those with which the successful Vickers-Vimy machine was equipped, had made the crossing in twenty hours—the estimated time—and had maintained an average of 1,800 revolutions each per minute, then each motor would have made 2,160,000 revolutions during the journey—4,320,000 revolutions for the two. Each piston, moving up and down the in-



THE BEARDMORE AEROMOTOR

This is a six-cylinder vertical engine developing 160 horse-power, the outstanding constructional feature of which is the copper deposited water jacket. At side, general view of engine showing overhead rocking levers actuating valves. At right (top), exhaust side of engine; below, the inlet side showing dual carburettors. This was one of the most serviceable aero engines used in the war.

terior of its cylinder, a travel of 5¾ inches in each direction, would have covered 440 miles. Seeing that the two engines total 24 pistons, the total piston travel thereof would have been 10,560 miles—an immense journey for such diminutive pieces of steel. During the twenty hours the valves would have opened and closed no fewer than 51,840,000 times, while the magnetos would have delivered current intermittently to the plugs which would have produced 25,920,000 sparks for the ignition of the charges in each engine.

We regard the mechanism of the modern aeromotor as delicate, but this performance conveys some idea of what it is able to do, while the actual speed achieved, namely, 117½ miles per hour for 16 hours, less three minutes, to cover 1,880 miles, brings home to one very vividly the remarkable capacity possessed by such a diminutive prime-mover, and also offers striking testimony to the super-excellence of British engineering skill, workmanship, and manufacture. It may be pointed out that in reality the Transatlantic flight represented a far heavier tax upon the aeromotor than it ever encountered upon the battlefield, notwithstanding the strenuous character of such work, inasmuch as the flights for the conduct of war were far shorter than are essential to commerce.

The Sunbeam-Coatalen Aeromotor

Another aeromotor which has a distinct claim upon the appreciation, not only of the British public, but of the world at large, is the Sunbeam-Coatalen, since this is the engine which has brought the negotiation of the Atlantic by airship within the bounds of possibility, thereby blazing the way of the air between the Old and New Worlds in true earnest. The designer of this aerial motor, Mr. Louis Coatalen, is a

pioneer blazer of the trail through the air in the fullest sense of the word, since his association with this field of activity dates from two or three years previous to the outbreak of war.

I have previously mentioned that the aeromotor is the logical development of the engine identified with the motor-car, and this fact is demonstrated very convincingly in connection with the Sunbeam-Coatalen product. In 1912 three Sunbeam racing cars, entered for the Coup d'Auto and the French Grand Prix, created a sensation. The first, second, and third places in the former race, open to vehicles not exceeding three litres engine capacity, were secured by the Sunbeams. The third, fourth, and fifth places in the unlimited class were also secured by the Sunbeams, which came first, second, and third in the Coup d'Auto class. Thus, the British car bore off in triumph the Coup d'Auto as well as the French Grand Prix team-prize for the open event, a feat unparalleled in British motor-racing circles.

The racing Sunbeams were driven by 6-cylinder engines, and encouraged by this striking success upon the road, the designer, who had long been turning his thoughts to the Way of the Air, decided to pursue this line of investigation. He took his 6-cylinder racing-car engine which had demonstrated its perfection, reliability and endurance so dramatically as the foundation for his intentions. Upon this he modelled his first aeromotor, the cylinders of which were 90 millimetres bore and the stroke 150 millimetres, while it developed 150 horse-power.

The Vee type was embraced, the cylinders being set in two rows of four each, at an angle of 90 degrees to one another, that is, at 45 degrees on either side of the vertical. As stated, it was essentially a racing-car engine, but the designer considered that it would be an adequate starting point for the

evolution of his train of thought. Being firmly resolved to conduct his investigation to a logical conclusion, despite the fact that aeronautical motor design was receiving little encouragement in these islands at the time, he emulated prevailing Admiralty practice in the construction of fighting ships, and introduced a class-naming system, the pioneer or initial effort being christened the "Crusader."

The engine completed, and its bench-tests fulfilling expectations, the designer decided to try it in the air. A proved British aeroplane being somewhat elusive, he went to Paris to purchase a Maurice Farman biplane. This was dispatched to Brooklands and fitted with the aeromotor. An enterprising pilot, who had won his reputation in the motor-racing world, to wit "Jack," now Sir John, Alcock, of Transatlantic flight renown, expressed his readiness to go aloft with the machine, and did so, bringing home the indisputable fact that this country was competent to design and build aeroplane engines, and that in the Sunbeam engine there was at least one aeromotor of native creation adapted to aerial service. With this machine the pilot established what was an interesting record for those early days, namely, an aggregate flight of 150 hours.

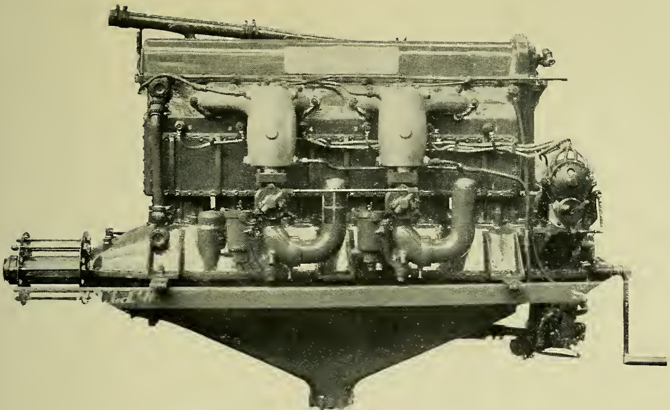
While these experiments in the air were under way, the designer had observed how certain improvements might be advantageously incorporated, and accordingly evolved a new motor, which he named the "Zulu," the feature of which was the increase of the bore of the cylinders by 10 millimetres to 100 millimetres, the "Crusader" length of stroke being preserved. This did not meet with the creator's satisfaction, so was abandoned in favour of another larger and more powerful type, the "Mohawk." This was a 12-cylinder engine with reversion to the bore of the "Crusader" type, namely, 90

millimetres, and the same length of stroke. The cylinders were disposed in two rows, the angle of the V being reduced to 60 degrees. This engine developed 225 horse-power. It was subsequently installed in a racing car purchased by an American motor manufacturing company, and incidentally broke the world's one hour record at Brooklands by covering 107·9 miles in the 60 minutes.

"Mohawk" did not satisfy the designer's demands, and forthwith underwent improvement, being fitted with cylinders of larger bore—similar in size and type to that of the "Zulu" —and was named "Ghurkha." In its improved form this engine developed 240 horse-power, and, being completed in October, 1914, may be said to represent the high-water mark of Sunbeam pre-war aeromotor evolution.

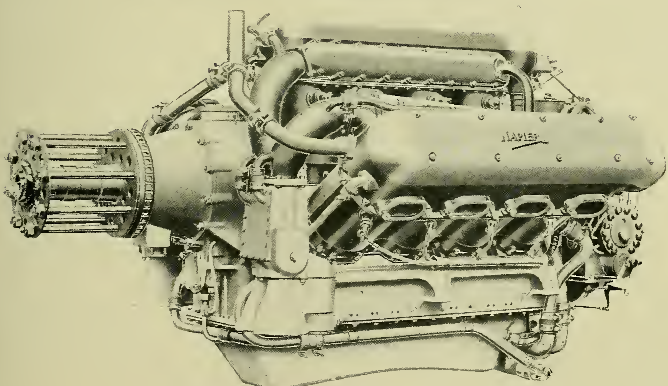
Meantime the first Sunbeam aeroplane had been making history, uneventful perhaps, but history for all that. After a brief sojourn at Brooklands it was transferred to the new aerodrome which had been established under private auspices at Shoreham, Sussex, where it continued its aerial career, enhancing its reputation for reliability and sustained performance. When war broke out this aerodrome was requisitioned by the Admiralty, and in this way the further course of the first Sunbeam engined aeroplane became summarily interrupted. Whether it was utilised by the authorities, by whom it was acquired, is not quite clear, but the probability is that, in view of our aerial weakness at the time, it was taken by the R.N.A.S. to France to assist Lord French, according to the dispatches of whom the Royal Naval Air Service played an heroic part during the opening stages of the war.

Hostilities may be said to have ushered in the second era of Sunbeam aeromotor history. In March, 1916, Mr. Coatalen, in response to the urgent desires of the authorities to



THE DRIVING FORCE BEHIND THE "BLIMP"

The 100-horse-power "Dyak" engine built by the Sunbeam Motor Car Company, which has been installed in many of the smaller non-rigid airships.



THE AEROMOTOR SURPRISE OF 1919

The "Napier" 12-cylinder, 450-horse-power engine. Many features new to aeroplane engine design have been incorporated in this motor. In running order, with water in jackets, it weighs approximately $2\frac{1}{2}$ lbs. per brake-horse-power.

concentrate his skill in the evolution of a new type of engine, produced the "Nubian." Accumulated experience had suggested several modifications, which found expression in this latest model. One great difficulty demanded subjection. This was the complete expulsion of the exhaust gases from the cylinders to allow a full charge of fuel to enter for the succeeding power stroke. The "Nubian" class represented the first determined attempt to solve this problem. There was a reversion to the earliest practice with eight cylinders disposed in two rows set at 60 degrees angle, the cylinders having a bore of 95 millimetres, with a stroke of 135 millimetres, the stroke thus being shortened, while the horse-power developed was 155. But this model was slightly improved, the "Nubian" class, which was actually put into service, having the two rows of four cylinders forming the "V," placed at 90 degrees. In order to ensure more efficient scavenging of the burnt gases and a fuller fresh charge, four valves were fitted to each cylinder—two inlet and two exhaust respectively.

Then came a new departure so far as Sunbeam-Coatalen practice was concerned. This was a 6-cylinder vertical engine, having a bore of 110 millimetres and a stroke of 160 millimetres. It was furnished with four valves to each cylinder, two sets of magneto ignition, as well as compressed air starter, while gearing was introduced to drive the propeller. This was christened the "Amazon" class, but it was shortly followed by another model, having slight modifications in detail, such as a single magneto as well as air and hand starter. Otherwise there was no difference, the energy developed in both models being identical, namely, 170 horse-power. Nevertheless, to distinguish the difference between the two they were named Amazon I. and Amazon II. respectively. As this class did not coincide with the steadily increasing

demand for power, a further vertical model was produced, the "Saracen" class. It was similar to the "Amazon" class except that the bore and stroke of the cylinders were respectively 122 and 160 millimetres, while the horse-power was higher, being 200.

The official pressure laid upon the creative and producing resources of the Sunbeam organisation suffered no diminution; indeed, if anything, it became accentuated. The pace in matters pertaining to the development of the aeroplane grew hot at once. Its precise military significance became appreciated by all the belligerents. The race for larger and more powerful machines exercised a repercussive effect upon the motor designers. In this respect we forged ahead at a rare pace, but the pressure applied had the effect of defining broad lines of evolution and the pursuance of successful types through progressively larger and more powerful models.

This tendency is very strikingly manifested in connection with the work conducted by Mr. Louis Coatalen, because among the wealth of ideas evolved and carried into effect by the Sunbeam Company may be found certain types which became the sires to large aeromotor families which achieved striking distinction. There are three notable Sunbeam-Coatalen aeromotor families, namely, "Maori," "Cossack," and "Arab," but it is probably the first-named which has achieved the widest measure of fame.

The father of the "Maori" family was Afridi, a 12-cylinder Vee engine, having a stroke of 92 millimetres and a bore of 135 millimetres, developing 200 horse-power. It was converted to "Maori" with increase of cylinder bore to 100 millimetres, the stroke being retained, 275 horse-power being developed. Four successive types of this class have been evolved up to the present, viz., I., II., III., and IV., and it

is Maori IV. which are installed in R34. Development in quest of power brought "Maniton," with cylinders of 110 and 135 millimetres, bore and stroke respectively developing 300 horse-power, and "Tartar" of similar power, but having single cylinders.

"Maori" IV. is one of the most successful of the many Sunbeam aeromotors. Its performance in R33 and R34 has been eminently satisfactory. Throughout the whole of the trial runs, especially the long-distance flights over the North Sea and the Baltic respectively, the engines behaved in a highly efficient manner, and in one or two cases, when heavy weather was encountered, it is freely admitted that their smooth, reliable running undoubtedly proved the salvation of the vessels.

In one North Sea flight a fog suddenly came on. The airship was unable to make land, and so the navigator, in his prudence, and confident of the staying power of his motors, decided to remain aloft, and owing to the persistence of the fog was kept cruising in the air for twenty-four hours.

The "Cossack" family is so named after the parent, which was of 12 cylinders, of 110 and 160 millimetres, bore and stroke respectively developing 320 horse-power. It proved so successful as to become standardised in two classes, I. and II., which differed only in certain details. But it produced a still more powerful unit—Viking I. and Viking II. respectively, the latter being utilised to engine the 55 "C.M.B.s," for which it was eminently adapted. The Vikings are monsters of 18 cylinders, of the same dimensions as "Cossack," disposed in three rows, conforming to the "Double Vee" arrangement, and developing 450 horse-power. Subsequently came "Matabele," developing 400 horse-power.

The founder of the third family was "Arab," an 8-cylinder

Vee engine, with a bore of 120 millimetres and a stroke of 130 millimetres, developing 200 horse-power, a feature being three valves per cylinder. This was succeeded by "Kaffir," of 12 cylinders set in three rows of four cylinders upon the double Vee principle. The cylinders were of 120 millimetres bore by 135 millimetres stroke, and the engines were fitted with two carburettors, one single and one double, as well as two 6-cylinder magnetos, while the propeller drive was direct.

The development of power now became decidedly pronounced, because the "Kaffir" was followed by the "Malay" —a huge engine of 500 horse-power. This was of 20 cylinders, disposed in five rows of four each, forming a star, the bore and stroke being 120 and 130 millimetres respectively.

The latest expression of aeromotor design by Mr. Louis Coatalen is the 12-cylinder "Sikh I." Here the number of valves per cylinder was increased to six. It is of the Vee type, with separately cast cylinders and four 12-cylinder magnetos.

Up to the moment of writing this not only represents the greatest achievement of the Sunbeam creative organisation in regard to power per unit, but the most powerful and largest aircraft engine in the world, since it is rated to develop from 800 to 900 horse-power. Contemporaneously with "Sikh I." another, "Sikh II., has been in hand. This is a different class of motor, being a 6-cylinder vertical engine, with the cylinders in a single row, but it will develop approximately 400 horse-power, or about 70 horse-power per cylinder.

Owing to the multitude of types which have issued from the Sunbeam works at Wolverhampton, which, as I have already mentioned, practically served as a huge practical national laboratory during the war, it is somewhat difficult to

THE DEVELOPMENT OF THE SUNBEAM AEROMOTOR.

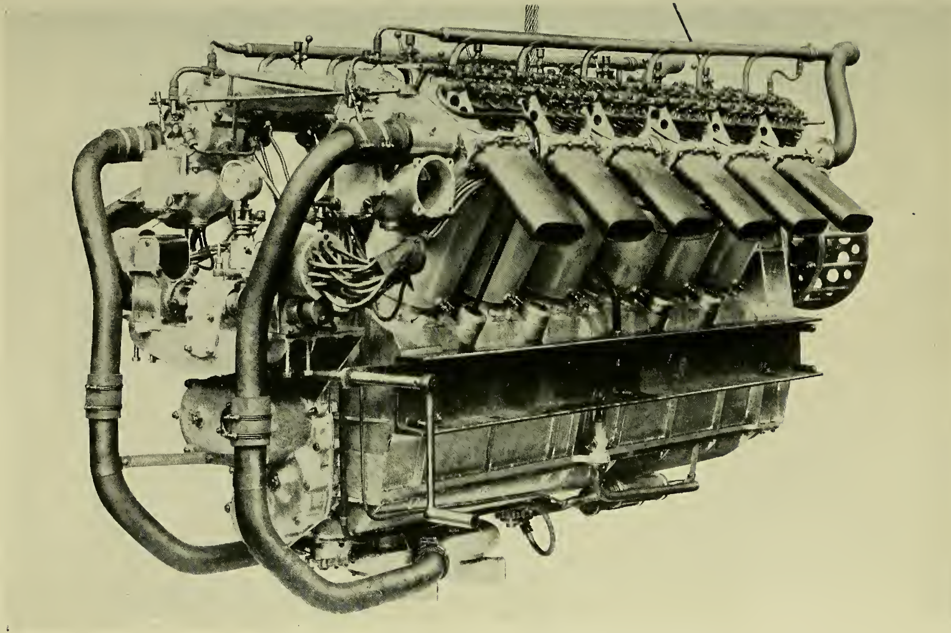
Name.	Type.	Cylinders. No of Cyls.	Valves per Cyl.	Bore.	Stroke.	Horse-Power.	Details.
				millimetres.			
			Pre-war period.				
Crusader	V	8	2	90	150	150	Side valves
Zulu	V	8	2	100	150	160	Side valves
Mohawk	V	12	2	90	150	225	Side valves
Ghurka	V	12	2	100	150	240	Side valves
			War period, August, 1914—November, 1918.				
Nubian	V	8	4	95	135	155	Standard type cyl. set 90° angle.
Amazon I.	I	6	4	110	160	170	2 mags., air starter, geared prop.
Amazon II.	I	6	4	110	160	170	1 mag., air and hand starter, geared prop.
Saracen	I	6	4	122	160	200	2 mags., air starter, geared prop.
Afridi	V	12	4	92	135	200	4 mags., inside exhaust valves, geared prop.
Maori I.	V	12	4	100	135	275	4 mags., inside exhaust, geared prop.
Maori II.	V	12	4	100	135	275	2 mags., 2 Remy's, inside exhaust, geared prop.
Maori III.	V	12	4	100	135	275	2 mags., 2 Remy's, outside exhaust, geared prop.
Maori IV.	V	12	4	100	135	275	H.M.A. R33 and 34, direct drive, water-cooled exhaust, governor.
Cossack I.	V	12	4	110	160	320	2 mags., air starter, geared prop.
Cossack II.	V	12	4	110	160	320	4 mags., air and hand starter, geared prop.
Viking I.	W	18	4	110	160	450	6 mags., air and hand starter, geared prop.
Arab I.	V	8	3	120	130	200	2 mags., outside exhaust, geared prop.
Arab II.	V	8	3	120	130	200	2 mags., outside exhaust, direct prop.
Spartan	V	12	4	105	135	200	single camshafts, air cooled, 2 mags., geared prop.
Manitou	V	12	4	110	135	300	2 mags., 2 Remy's, outside exhaust, geared prop.
Matabele I.	V	12	4	122	160	400	4 mags., air and hand starter, geared prop.
Matabele II.	V	12	4	122	160	400	2 mags., air and hand starter, direct prop.
Tartar	V	12	4	110	135	300	2 mags., single camshafts, geared prop.
Kaffir	W	12	3	120	135	300	2 6-cyl. mags., 1 single carburettor, 1 dual carburettor, direct prop.
Malay	§	20	3	120	130	500	1 single and 2 dual carburettors, direct prop.
Bedouin	Λ	8	3	120	130	200	Inverted "Arab," 2 mags., outside exhaust, direct prop.
Dyak	I	6	2	120	130	100	monobloc cyl., 1 mag., 1 Remy, direct prop.
Sikh (12)	V	12	6	180	210	800	Single camshaft, 4–12 cyl. mags., separate cyls., geared prop.
Sikh (6)	I	6	6	180	210	400	Single camshaft, 2–6 cyl. mags., separate cyls., geared prop.

V=Vee type. I=Vertical type. W=Double Vee type. § 5-pointed star.

follow engine development lucidly and chronologically for the reason previously stated, and because motors were required to satisfy every branch of the air service—aeroplanes, seaplanes, and airships, both rigid and non-rigid. But in order to demonstrate the inexorable demand which obtained for power—and more power—I have set out the accompanying table (see previous page), which is somewhat interesting, because it concisely shows how the Sunbeam aeromotor has been evolved by Mr. Louis Coatalen from his amazingly successful racing-car engine. It is additionally remarkable because it represents virtually only eight years' work.

In so far as record of performance is concerned, space will not permit a full recapitulation, because the Sunbeam aeromotor has served in so many parts of the world in all classes of flying machines. But one story may perhaps prove interesting.

When the Belgian Military Expedition was organised to co-operate with the British forces in East Africa to drive the enemy from Lake Tanganyika, five Short seaplanes fitted with Sunbeam-Coatalen engines were dispatched to that inland sea. The machines were dismantled and laboriously transported in sections across country to the shores of the lake, where they were reassembled. The task of chasing the enemy from the lake proved arduous, but the seaplanes were always out and about, irrespective of weather, searching the sheet of water from end to end for signs of hostile vessels, and no losses were incurred in the task. Upon the fulfilment of this duty, there being no further work for the five seaplanes in Africa, they were once more dismantled, repacked, carried across country again to the coast, and sent home to be drafted with the engines which had seen such prolonged and hard service in Central Africa to Dunkirk. It was a striking testi-



THE MOST POWERFUL AEROMOTOR OF 1919

The Sunbeam "Sikh" of 18 cylinders developing 800-900 horse-power, designed for airship propulsion

mony to the reliability, durability, serviceability, and workmanship of these seaplanes and their engines, and would probably prove somewhat difficult to equal during the war.

But, of course, the outstanding triumph of the Sunbeam-Coatalen aeromotor is in connection with the trip made by R34 from England to New York and back in July, 1919, involving a round trip of 5,100 nautical miles. The outward journey to Mineola, Long Island, via Newfoundland, a distance of 3,100 nautical miles, in 108 hours 12 minutes, not only constituted the longest flight accomplished by dirigible up to that time, but was sensational from the exasperating adverse conditions encountered.

The R34 carries five aeromotors of the "Maori IV." class, each developing 285 horse-power. Throughout the first 70 hours the vessel ran on only two of her five engines at a time, these giving her an average air speed of 38 knots. The petrol consumption was 4,900 gallons, which is equivalent to about 1.6 gallon per nautical mile. Had better weather been encountered not only would the journey have been covered in less time, but a more economical fuel showing would have been recorded. But the heavy head winds experienced on the last lap of the journey necessitated crowding on power, and even then she was only able to advance slowly.

The return journey was made in shorter time. Whereas a somewhat circuitous route had been followed on the outward run to enable Newfoundland to be made, the homeward jaunt was direct from New York to Pulham, Norfolk, a distance of 3,000 nautical miles. The return run served to emphasise the value of favourable weather and wind conditions upon speed in no uncertain manner, because the airship attained and maintained for a brief period a speed of 83 miles an hour on four engines. Unfortunately, about halfway across the

Atlantic one engine in the stern gondola had to be cut out owing to mishap, the airship now being dependent upon three engines, and speed was accordingly reduced. In view of the heavy gruelling to which the engines had been subjected on the outward run, considering that they had been in service for some time previously and had made many notable long-distance and prolonged flights, the fact that the engines held up so well offered striking testimony to Sunbeam-Coatalen design and workmanship.

The whole of the machinery, including the engines, clutches, intermediate shafts, reduction gear, propeller shafts and propellers, piping, radiators, oil and water tanks, etc., for R33 and R34 were manufactured and erected by the Sunbeam Company. The Maori IV. engines, designed essentially for airship propulsion, have 12 cylinders mounted in two rows of 6 cylinders each, in Vee form at an angle of 60 degrees. The bore and stroke of the cylinders are respectively 110 and 135 millimetres, each cylinder having four overhead valves actuated by two cam-shafts to each row of cylinders, the cam-shaft drive being through a train of gears. The articulated system is adopted for the connecting rods, while a flywheel is fitted to the crank shaft.

These engines are designed to run at 2,100 revolutions per minute, giving 275 brake-horse-power. Four carburettors are fitted, the feed being either gravity or pressure, while ignition is carried out by two 12-cylinder magnetos. The water-pump is of especially large dimensions, while a governor is fitted so that when the engine speed attains 2,500 revolutions per minute, or when the oil pressure falls below 20 lb. per square inch, the ignition is cut out, thus bringing the engine to a standstill for attention to either of these two details. Thus it will be seen that an excellent safety device is incor-

porated, set at two extreme limits, to avoid over-running the engine and to preserve it from disaster through lack of lubrication. Both hand and compressed air starting facilities are provided for setting the engine in motion. The exhaust pipes are fitted with a special arrangement for cooling the water.

The flywheel carries one element of a friction clutch, driven therefrom by means of a series of composite leather and brass driving pieces, which are interposed to equalise the stresses on the teeth of the main wheels. The clutch itself is of the multiple disc type with a single central spring, and contains a series of ten phosphor bronze plates of special alloy to make frictional contact with ten similar plates of steel. The central spring is operated by a lever on the control station in connection with the engine in such a way that the pressure of the spring is balanced when driving, while the end load on the crank shaft is reduced to the minimum when declutching. From the clutch the power is transmitted by means of an intermediate shaft, fitted with a dog coupling, for permanent disengagement when necessary, to a gear-box fitted to the after-end of each gondola in which the motor is mounted.

The gear-boxes are of three types. In the forward gondola the gear-box is a plain reduction type without reverse gear, similar in principle to that fitted to motor-cars, reducing the crank-shaft revolutions from 2,100 to 540 propeller revolutions per minute. The second gear-box is of reversing type, and is used on the wing gondolas, two of which are set in transverse line. The reduction is similar by means of sliding gears, and the direction of rotation of the propellers thus can be changed to admit driving astern or for manœuvring purposes. The third gear-box is a special reduction type, in which two pinions are used, both engaging with one common

spur wheel attached to the propeller. This is fitted to the stern gondola, which is of larger dimensions than the others, because it carries two sets of engines driving one propeller. All gear-boxes are of similar detail design, the gear-wheels being of large diameter, and fitted with pumps to ensure a constant supply of lubrication to the teeth, bearings and other parts. The oil for the gear-boxes is carried in special small tanks, which are fitted close to the gear-boxes.

The radiators are coupled up to the engines and to an aluminium tank by aluminium piping, the tank being set in the hull of the ship. Special arrangements are made to enable the effective cooling area of the radiator to be adjusted to suit the surrounding air and the speed of the engines. Branch pipes are supplied for heating when on the ground, and to supply cold water for stationary trials. The petrol services are connected to filters and petrol cocks on the gondolas, the filters and attendant gear being in duplicate so as to allow the engine to be switched over from one fuel feed to the other as desired for cleaning purposes, thereby dispensing with the necessity to stop the motor to conduct this operation.

In addition to the usual lubrication fittings supplied with the engine there are additional special oil-cooling tanks placed outside the gondolas. These tanks are in direct communication with the oil circuit on the engines through a series of connections made with oil cocks fitted with indicating plates. Thus the quantity of oil passing through the coolers may be adjusted to meet the running and temperature conditions, and a fresh supply added to the oil in circulation from a tank which is mounted in the main structure of the ship. The oil circuit also incorporates a special filter, so arranged that one half of the filter is continually in use while the other section is being taken apart for cleaning purposes.

The trials which had to be fulfilled by the builders before the vessel was taken over were of an exacting character, including not only bench tests, but air-borne trials in the shed, and flight trials of eight hours' duration. The two-bladed propellers were also manufactured by the Sunbeam Company. These propellers, of which the largest has a tip-to-tip diameter of 19½ feet, were all tested by the Admiralty upon a special rotary apparatus, which was erected for the purpose, before being installed upon the ships. While the company is responsible for the design and construction of the whole of the propelling machinery and incidental gear, the general arrangement thereof was carried out upon data supplied by the Admiralty, which, as is well known, has been responsible for the construction of these huge dirigibles.

H.M.A. R33 and R34, however, represent but a stride in the development of these craft. Larger and more powerfully-engined craft, having higher speeds, are under construction. Previous to the crossing of the Atlantic by R34 the authorities were so satisfied with the performances of this vessel and her sister, R33, that contracts were placed for four further vessels. These later ships, it is anticipated, will not only be able to cross the Atlantic, but to venture to other and more remote parts of the world, involving longer trans-ocean passages. Indeed, it is not too much to hope that before 1920 has passed regular services, both across the Atlantic and to distant parts of the Empire will have become instituted.

The secret of successful long-distance flying such as has been recorded by the aid of the dirigible is essentially dependent upon the efficiency and reliability of the engines, and the Admiralty are evidently completely satisfied with the performance of the Sunbeam-Coatalen motors which have been designed and built specially for this work.

In view of the remarkable development of aerial navigation by means of the dirigible as fostered by British enterprise within the past two years, it is interesting to hark back a few decades. In the early days of aviation a solitary motor unit developing 20 horse-power was regarded as a somewhat daring undertaking. Captains Renard and Krebs, who really pioneered the Way of the Air by dirigible with *La France* in 1884 and 1885 relied upon electricity as their source of energy, the electric motor developing 9 horse-power. But it was Santos-Dumont who really ushered in the contemporary era of aerial navigation, and conclusively established the suitability of the petrol engine for this work with *Santos Dumont No.* 6. With this vessel, measuring about 100 feet in length, and which was of the non-rigid type, capable of carrying only one person—the pilot—the intrepid and indefatigable experimenter, on October 19, 1901, carried off the Deutsch prize of £4,000 offered for the first round or circular journey, by flying from St. Cloud, doubling the Eiffel Tower, and returning to his starting point, the journey occupying 30 minutes. And the motor with which this historic dirigible was fitted developed only 16 horse-power! Truly the development of the lighter-than-air flying machine may be described as rapid. It also serves to bring home to one the extraordinary development of the aeromotor.

CHAPTER VIII

The Testing of an Aeromotor

IT is better to be safe than sorry. This is the guiding maxim in regard to aeromotor construction. Everything depends upon the reliability and durability of the propelling machinery under ever-varying conditions. The engine must be free from mood and fickleness, and to assure this end being completely fulfilled, every precaution which is humanly possible must be observed in its construction. The aeromotor, when aloft, is called upon to work under conditions which this type of engine experiences in no other field of its application. It has to run against the collar, or under full load the whole time it is in service. This particularly is the case in its application to the contemporary aeroplane. So far as the airship is concerned, the circumstance that the propelling equipment is divided into a certain number of individual units, coupled with the ability to travel at varying speeds owing to the vessel being dependent upon an extraneous force—hydrogen—for its ascensional effort, enables the engine units to be worked in shifts. Thus, upon the voyage of the H.M.A. R34 across the Atlantic, only three out of the four propelling units were working at one and the same time. This was distinctly advantageous, inasmuch as it enabled the desired cruising speed to be maintained with an ample reserve of power, to meet any sudden contingency.

How long does it take to build an aeromotor? I am not

referring to a new or experimental model which, as we all realise, is likely to occupy an inordinate length of time, seeing that each part may demand finicking adjustment or finish, but to the commercialised model, all parts of which have been rigidly standardised to assure output. If the question were put to the average individual, his reply would undoubtedly be governed by memories of the producing capacity of a certain motor-manufacturing organisation, and the time involved would probably be assessed at so many hours—perhaps one or two days. But the reply would be hopelessly wide of the mark. The modern aeromotor is not a product of hours or days, but of weeks. From the moment the raw material is taken in hand, or a tool lifted, until the engine is accepted as being ready for the aeroplane, at least three months elapse. And it must be remembered that the mechanics are engaged upon the engine for the whole of this time. It seems incredible, but it is nevertheless true, and it is entirely due to determination to honour fully the hoary precept that "it is better to be safe than sorry."

The aeromotor is a masterpiece of mechanical construction. Every part, no matter how small or relatively insignificant it may appear, or the particular rôle it is designed to fulfil, must be as sound as the proverbial bell. Where close measurements have to be rigidly observed to the last ten-thousandth part of an inch, the slightest departure from that measurement is certain to bring about the rejection of the piece involved. The micrometer gauge is the autocrat of the engine-construction and erecting shop; every part is subservient to its reading. Certain parts may not demand absolute compliance with the rigid standard set down, and a certain margin either in excess of, or less than, the stated measurement—plus or minus, as it is termed—is permitted by the designer. Other

parts he stipulates shall be absolutely dead true, and it is this absence of any margin which calls for such wonderful precision in manufacture—precision which heat radiated from the hand in holding the part is likely to affect adversely.

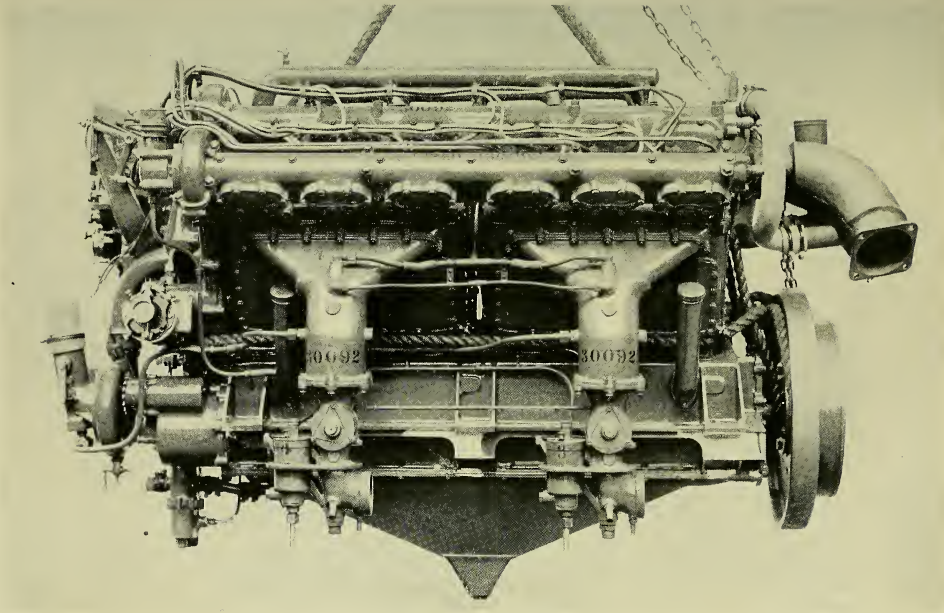
It is when the many thousand pieces have been truly assembled, when the final screw has been adjusted, that the engine is subjected to its most severe and exacting tests. The practice observed at the Wolverhampton works of the Sunbeam Company, the cradle in which the well-known aero-motors designed by Mr. Louis Coatalen are raised, is as relentless as could be conceived. Latent flaws in material which no amount of human foresight or examination could discover, the smallest errors in workmanship, deviation from the rigid specification set down in the preparation of the steels and alloys employed, and which may have escaped detection during the initial test of raw materials, are almost certain to be revealed in the course of the trials through which the assembled motor is submitted before installation in the aeroplane or airship. It would be fatal to act otherwise. So much depends upon the motor; it is the nerve upon which the lives of the aviator and his passengers depend.

The first task is to run-in the engine; to bed all its parts so that they may run smoothly and rhythmically. An engine, no matter how beautifully it may have been assembled, is likely to be a trifle stiff. In a way it resembles the athlete who has suspended training for a prolonged period, and who suffers upon resuming his rigorous preparations. The motor is rigged up on a bench and, as running-in is a more or less perfunctory task, it is driven on coal-gas, which is cheaper than petrol and quite as effective for the purpose. The gas is drawn from the main and fed direct to the cylinders, the carburettor being unnecessary. When the connec-

tions have been made the engine is started up and is left to run unfettered for four hours. Possibly, now and again, the mechanic in charge may come round and liven the engine up by giving it a burst of speed for a few moments; but for the most part it is left to run at its own sweet will, or rather at the fixed speed, such examination as it is given meanwhile being rather to make certain that lubrication and water-cooling are proceeding normally.

At the end of the four hours' run the engine is taken down and removed to the shops. Here it undergoes complete dismantling, every part being separated from its fellow. Each part is closely scrutinised to ascertain whether or not any latent defect in the metal has asserted itself, whether workmanship is at fault, or whether any individual piece gives any signs of succumbing to the strain imposed. The examination proving satisfactory, the motor is reassembled and taken to the testing bench. Now it is connected up to a petrol supply system, the carburettor and magneto being coupled up and adjusted, because the aeromotor has to undergo a further four hours' run, but under conditions broadly analogous to full load. Petrol is employed in this test because, among other things, it is necessary to discover whether the fuel consumption coincides with the calculations made by the designer. The engine, being connected up to the brake, enables other technical data, which it is incumbent to discover, to be forthcoming. Therefrom it will be possible to determine how far the specifications have been fulfilled.

A second dissembling follows the completion of this four hours' run, every part again being closely examined, not only for defects which escaped the first running, but to ascertain whether any signs of discoloration of metal are apparent. If so, the part is rejected. Moreover, the gauge is brought



ANOTHER MEMBER OF THE "SUNBEAM" AEROMOTOR FAMILY

The "Maori" 18-cylinder engine, designed by Mr. Louis Coatalen for airship service. It develops 285 horse-power. Five of these engines are installed in H.M.A. *R. 33* and *R. 34*. Their efficient working has been striking, and, in one or two cases, when the vessels encountered bad weather the reliability of the engines proved their salvation.

freely into play, the idea being to determine deflection of parts, if such has occurred as a result of the actual running under load. For the third time the motor is rebuilt to undergo a third test of four hours' hard running, followed by a fourth stripping and close inspection.

Now comes the crucial test, which is as near actual aerial conditions as trials on the ground will permit. Incidentally, this is the trial which determines whether or not the aeromotor shall be permitted to go into the air as the vital nerve of the aeroplane.

Outside the shops is a skeleton building in the fullest sense of the word, being nothing but two end walls supporting the roof. This building is subdivided into compartments by partitions, recalling nothing so much as an extemporised or farmyard cattle stall. Each compartment accommodates a wheeled chassis, the exact counterpart of the under-carriage of an aeroplane complete to the last detail—rubber-tyred wheels and springs or amortisseurs to absorb shocks, jars, and vibrations. The wheels are heavily scotched, and to make additionally sure they shall not move laterally, they are shored up to the hubs of the wheel axles with heavy blocks of wood. Finally, they are secured to the ground by anchors, the latter, however, being a trifle slack, to extend a certain free vertical movement to the chassis. On the body, which is small and squat, is an engine frame, designed to carry a motor and two-bladed propeller.

The rear face of this chassis recalls to mind the footplate of a railway engine. Numerous dials and recording instruments connected to gauges are carried upon what is virtually a dashboard. On the left-hand side is a gas cylinder or bottle charged with compressed air. The footplate is just large enough to accommodate the tester and his assistant,

while on either side are running boards to facilitate access to both sides of the engine while it is working.

The motor, possibly of twelve or eighteen cylinders, scaling no more than 2½ lb. per horse-power, has been reassembled once more, erection being carried out to the last detail, including carburettor, magneto, oil-lubrication system, and compressed-air starting gear. It is picked up by a crane from the trolley upon which it has been brought to the testing station, is swung through the air and lowered into position upon the bedplate of the chassis. It is geared up to the propeller and bolted firmly in position by the testing mechanic and his assistant. All leads, pipes, and other gauges are connected up to the dashboard, including controls—throttle and ignition. The mechanic takes a final run over the engine to see that all is in order, and makes sure that the protecting bar has been lowered in front of the compartment to prevent an unsuspecting workman from walking into the stall to be caught by the invisible whirling propeller. While one is watching the final operations one catches sight of the vivid red notices staring from here, there, and elsewhere, warning wanderers to pass the testing station at a respectful distance to the rear. We who are following the preparations intently retire discreetly behind the friendly partition as the tester swings down on to his footplate, and takes a last look round to satisfy himself that all is clear.

The tester turns the lever connecting the compressed-air cylinder with the starting gear of the engine. The motor instantly responds, as is evident from the slow, steady rotation of the propeller. At the same time he moves the throttle. A vicious bark cleaves the air, increasing in intensity, proving that the engine has been swung over to, and is picking up on, its natural fuel—petrol. The compressed-air supply is cut off,

and the engine is slowed down gradually until the propeller settles down to a lazy, half-hearted gait. The engine is just "ticking over," as the airman calls it, and is permitted to run at this pace for some minutes. "Warming her up," the tester describes this lazy running, and it is apt, because that is precisely what is happening.

But during this warming up the tester is on the alert. He is swarming over the engine, feeling her everywhere, trying all bolts to see that she is well and truly bedded down upon her frame, and trying all connections to see that they are tight. If anything should be slack it would be revealed with dramatic suddenness a few minutes later.

Satisfied that all is well, the tester regains his station. He shouts a warning to us to place the thin partition well between ourselves and the engine. We have scarcely done so when the low purring of the engine gives place to a nerve-racking roar, as of a thousand machine-guns firing at their hardest. We peer timorously through friendly chinks in the partition. The tester has switched forward the control and the ignition levers, and the engine appears to have become endowed with savage life. Long ribbons of flame burst from the exhausts, while the din is terrifying. Of the engine scarcely anything can be seen; she is wreathed in fire and smoke of burnt petrol gases and oil. The propeller itself is invisible. There is only a faint filmy shadow, crescent in shape, and apparently standing on one of its horns. It is that cast by the rapidly revolving blades of the propeller, which is now approaching its maximum speed. The roar increases, but we appear to have lost all sense of sound. The brain has been numbed by the roar. We see the tester and his colleague crouching down behind the dashboard, eyes glued to the gauges, and hands on controls. The spectacle is terrifying. The engine now being

"all out," the propeller is exerting such a pull on the chassis as to cause the footplate to rear high into the air. It is straining and tugging at its chains anchoring it to Mother Earth, and we reflect upon the precaution of such a strong, restraining leash, otherwise the frame, if it did not actually mount into the air, would lurch forward, to trundle like a winged duck over the ground until the propeller blades were pulled up short by the earth, to fly in pieces in all directions. The kick and jump upon the footplate is so vicious that we wonder how the tester and his assistant can possibly keep a foothold.

As the dancing, lurching, and rolling continue we hurriedly reflect. The aeromotor is built to make 2,500 revolutions a minute. A hazy picture can be formed of the strains which are being imposed upon the slender-looking moving parts, and how the spider-like piston rods are racing up and down their cylinders at a speed so fast as to defy observation by the human eye; how the valves are popping up and down in such rapid succession as to appear to be stationary; how the sparks are literally flying from the plugs in response to the contacts established by the magneto; and how the petrol is being sucked up in a huge stream to be ignited, the gas, after fulfilling its work in small charges, rushing with terrific force in the form of spent flame from the exhausts.

Reflection undermines discretion, and so, inadvertently, we push our heads round the corner of the partition. The next moment we repent of our folly, for it seems as if our eyes have been wrenched from our heads. If we are intrepid we thrust out an arm, to experience instant intense pain, as if the limb had been torn from the shoulder. However, the experience has conveyed a lesson. It has taught us something of the terrific blast of air created by the propeller of an aeroplane rotating at full speed in a confined space. Toss a post

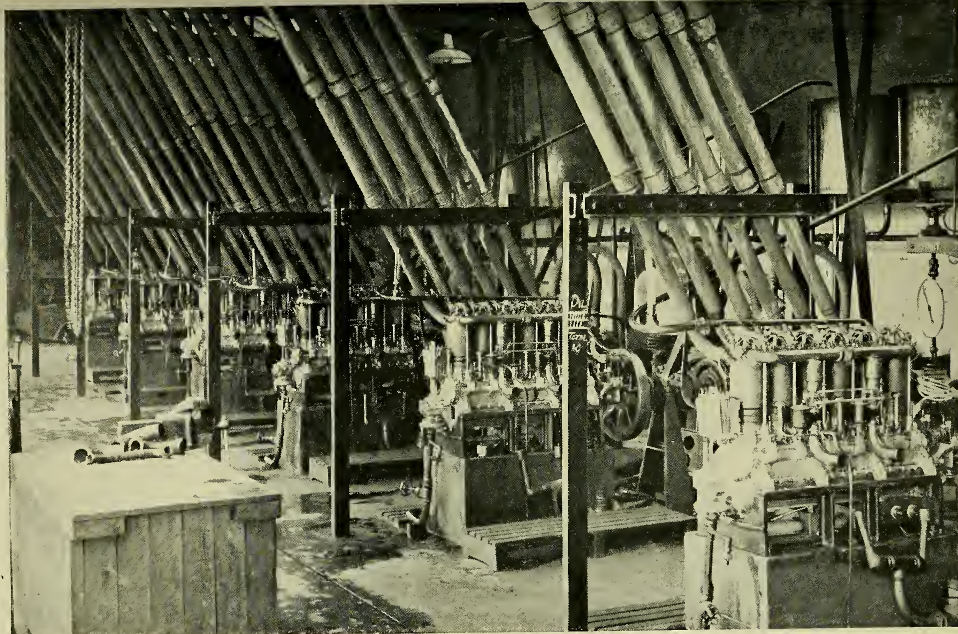
card into the air-stream and away it goes, scurrying over the buildings, impelled by the artificial gale. Stroll round to the front of the stall to lean upon the protective cross-bar guarding the propeller. There is no air-blast here, but a powerful sucking action, the propeller striving to draw us into its embrace. Then we commence to realise, somewhat vaguely perhaps, why it is an aeroplane can fly. Surely such a force as is experienced would be able to pull a ton or more through the air with but little effort.

The roar dies down, although it is scarcely realised at first. The chassis sinks back upon its wheels as if loath to part with its sense of speed and power. But the test has not been completed. After a short rest, or rather a spell of "ticking over," the while the tester runs over the engine to see that everything is O.K., the controls are once more moved, and the motor again is brought to life. Now the tester indulges in a form of harnessed aerobatics. He knows full well, when the aeroplane gets aloft, that the machine will be subjected to a weird variety of stunts to which the engine will need to respond. So the tester strives to reproduce these evolutions upon the ground. He has tamed the engine; it is now as willow in his hands, answering freely to every movement he makes. He rattles away at the controls, moving them forward and backward as if frenziedly working a Morse transmitter. This moment the engine is tearing and roaring at the "all out"; the next it is slowed down to almost a dead stop. Perhaps it is cut out altogether, only to be swung forward to its maximum in one sweep—a "burst." To and fro the throttle is swung, and the chassis dances, jumps, twists and turns in a frantic manner, in sympathy with the power exerted. The jolts and jars imparted to the engine seem to be sufficient to shatter it to pieces, but the aeromotor is designed to withstand just

those strains. After all they are no worse and very little different from what they will have to withstand when landing or "taxying." We marvel at the propeller being able to withstand such violent oscillations of speed, but the balance of the engine is much more impressive. We realise how beautifully it has been designed and made to the uttermost detail, how extremely sensitive it is, and how remarkably responsive to every variation of control. If there were any error in the correct proportioning or balancing of the parts it would be revealed speedily. Faulty balance would be attended with erratic turning movement of the crank shaft, which would be communicated to the propeller. The latter would experience the full brunt of the defect, because here the defect is distinctly magnified. So much so that, if the eccentricity upon the part of the engine be very marked, the blades of the air-screw will snap like carrots. This is the test which alone can reveal these latent defects of the motor. Successful "stunting" on the testing chassis proves that the aeromotor can be trusted in the air.

For four hours the aeromotor is called upon to withstand these remarkable and devastating evolutions. At the end of this period it is stopped, released from the chassis, re-transferred by the crane to the trolley, and hurried back to the workshops. Again it is relentlessly torn to pieces to have every component part critically examined, only more searchingly, if such be at all possible, than upon the three previous occasions. Approval being extended, the engine is once more reassembled and passed for service; it may now be installed in the aeroplane or airship.

After such a remarkable gruelling, four successive dissections and four re-erections, one wonders how an aeromotor can possibly fail in the air. Survival of the tests imposed would



PUTTING THE AEROMOTOR THROUGH ITS PACES

This striking plant was laid down by Crossley Motors, Limited, for testing every Beardmore engine built by the firm, under full-load conditions, before installation in the aeroplane. It was one of the finest and most complete equipments of its character, devised for this vital purpose, in this country.

seem to render it able to withstand anything and everything. As a matter of fact an aeromotor very rarely gives out through any inherent defect while in the air. Such an eventuality can nearly always be traced to some contributory cause or the failure of an accessory. Hawker's Rolls-Royce engine gave out during his trans-Atlantic flight through a piece of solder becoming detached, under excessive vibration, from the radiator and finding its way into the water circulation system. A few specks of dust will block the carburettor jet. The platinum tips of the magneto wear and disturb the regularity of the make-and-break. The engine is over-lubricated or fails to receive as much oil as it requires. There are a hundred and one possible mishaps to the auxiliaries which are quite capable of upsetting the smooth and designed working of the engine, but it is very rarely that the latter itself develops a defect. Of course, now and again a component part will collapse even after standing up to all tests, possibly because the metal of which it is composed has reached the limit of its endurance, and becoming tired gives way. But these are factors beyond human foresight and ingenuity.

At times the designer, even after the foregoing tests have been made, will wander among his aeromotors and instruct this, that, or some other engine, selected haphazard, to be put upon the testing chassis once more, and be given long spells of hard running at full speed for an aggregate of 150 hours or more. Occasionally he will even request one to be put up to be run to destruction; that is, run until it is brought to a full stop from the collapse of some component part. But nowadays, owing to the excellence of the materials employed, the precision and care with which the component parts are fashioned, and the care and skill with which they are assembled, tests to destruction are a wearying process. The man is

likely to tire long before the motor goes to pieces. No matter from what point of view the aeromotor may be considered, it must be conceded as being one of the most beautifully designed and fashioned pieces of mechanism yet evolved by man.

In view of the attainment of such a high degree of excellence and perfection, one naturally is disposed to wonder what the cost of such an engine may be. This is a difficult question to answer; it is affected by so many factors. Power, number of cylinders, and other points affect the issue, but it may be safely asserted that the contemporary aeromotor may be said to vary in cost from £1,200 to £1,600 and upwards. The cost of the engine alone is likely to react against the aeroplane ever becoming a cheap machine. It is an engine designed for a special and perilous duty; one into which the question of cost cannot as yet be permitted to enter. Every consideration must be sacrificed to absolute reliability, durability, and endurance under every and any conceivable condition.

CHAPTER IX

An Airship in the Making

THE stately passing overhead of a mighty dirigible; the easy grace with which it sweeps to the right or left, up or down, according to the movement of its helm, never fail to exercise a profound fascination. It stirs the emotions to a degree never approached by the aeroplane, even in the days when flying was young, while prolonged acquaintance with the spectacle does not appear to stale its novelty. In these islands, perhaps, such an attitude of sustained interest is to be expected, the big airship being of comparatively recent date; but the circumstance that familiarity does not appear to breed indifference is proved by the excitement with which such aerial craft are regarded in those countries where they have been in daily use for many years past, as for instance Germany. There the flight of a Zeppelin is always followed with keen enthusiasm, while dense crowds attend the ascents and descents.

Why the dirigible should prove such an extraordinarily powerful lodestone is not difficult to explain. That such a huge creation, challenging an Atlantic liner in length, should be brought under such complete and easy control, to move whither man desires in the vast aerial ocean, constitutes a monumental triumph for the ever-conquering forces of harnessed science. The effect wrought upon the lay mind is undoubtedly psychological. The aeroplane, even when of

relatively large dimensions for such dynamic craft, is as the gnat in appearance. It lacks immensity. It appears to be endowed with the curious capacity to dodge the hostile forces of Nature, its diminutive size and high speed doubtless fostering this illusion, whereas, as a matter of fact, it really takes advantage of these adverse influences to achieve its success. On the other hand, the dirigible, from its huge dimensions, always seems to convey the impression of deliberately courting the antagonism of Nature, and to invite her blind forces to do their worst. To the lay mind, fully conversant with the power of the wind and the devastation it is able to wreck when thoroughly roused, the ability to contrive a monster craft able to overcome those forces is regarded with unfeigned wonder.

This feeling is further prompted by the knowledge that in carrying out his conquest ambitious man is torn between divers conflicting forces. We know that the ascensional effort or capacity of the dirigible to float in the air is due to recourse to an agent lighter than the air itself. We are also fully aware that the vessel, from its proportions, must necessarily represent an imposing weight, and that consequently a spirited struggle between lift and weight must be constantly waged. We are similarly fortified with the knowledge that to overcome the resistance of the air the dirigible must be equipped with an adequate propelling effort, and that this must be decidedly superior to the force of the wind, otherwise a straight course could never be maintained. Finally, we are cognisant of the fact that in moving forward the airship must encounter intense resistance from the air, and that here again another contest between propelling effort and wind resistance must be waged. Consequently, fully reflecting upon the conditions which prevail, and which would seem to be so over-

whelming in their cumulative effect, one is naturally disposed to ask, "How is it done? Why is such complete victory over the air possible?"

The answer to these obvious inquiries constitutes a fascinating romance of Britain's endeavour. As a nation she may have started late in the day to achieve the decisive conquest of the air by means of the big airship, but, it is significant to remark, in the belated effort which she put forth she has been able to out-distance her competitors. At this moment Britain possesses a larger and more imposing airship fleet than all the other nations put together. She has been able to reap where the foreign pioneers did sow; she has been in the position to profit from their mistakes.

Airship construction, particularly of the monster rigids such as is typified by the "R" class, designed for service duty, is a phase of craft distinctly individual. The manufacture of aeroplanes may be assumed by a firm completely ignorant of the work at a moment's notice but not so the dirigible. The essential requirements are so peculiar and so difficult to fulfil. In the first place a Zeppelin—the term is used in the distinctive sense, and applying to the monster rigid dirigible—aircraft construction establishment cannot be planted in any spot. Selection of site must be conducted with as much care and skill as that attending discovery of a new shipyard, while an imposing area of territory must be roped in for the purpose. The area secured must be of a level character, while the surrounding country must be of such a nature as to facilitate the low altitude manœuvring of the craft, as well as affording her ample room in which to get away or to make harbour. Local meteorological conditions have also to be studied closely, since obviously it would be suicidal to establish a Zeppelin yard upon a bleak, windswept plateau.

Once the site has been found, the plotting and laying out of the requisite buildings and plant require to be conducted with careful deliberation. The many problems identified with the task may be gathered from the circumstance that, although three or four firms are engaged in the construction of these huge craft in this country, there is only one yard in the whole of these islands which was intentionally selected and equipped with plant wholly and exclusively for the construction of these vessels, which is completely self-contained, even to generation of hydrogen, and which was found to be so peculiarly efficient and adapted to the task as to lead the authorities to discuss its acquisition for the country.

When it was realised, from the trend of war, that it would be absolutely necessary for Britain to have an imposing homogeneous fleet of mammoth dirigibles in being, the problem arose as to how we might become possessed of this additional fighting unit upon the requisite scale within the minimum of time. Certain firms, from the vastness of their plants, elaborate organisations, and comprehensive character of their manufacturing operations, offered to assist the Government, and their co-operation was accepted. In each instance, however, the work was attacked somewhat in the light of a side line, one which might be abandoned at a moment's notice without imperilling the existence of the firms concerned.

But there was one firm whose activities have been identified with aeronautics for many years, and who had been studying the Zeppelin problem along distinctive lines. The principals and their technicians had elaborated certain ideas and proposals, but lack of facilities militated against their being fulfilled. The firm thereupon approached the Government, explained its intentions, and suggested that a "yard" devoted wholly and exclusively to the production of these

huge craft should be established. The suggestion was accepted, and thereupon the firm in question searched the country high and low for a suitable site. Appreciable time was occupied in the fulfilment of this preliminary, and, as a result of careful deliberation, it was found that there was only one feasible centre in the country where such a yard might be laid out to the utmost advantage from every point of view. This was at Cardington, within easy reach of the market-town at Bedford, but which, at that time, was but a dot upon the map. The authorities acquiesced in the selection of the site, thereupon necessary constructional work was put in hand.

The enterprising firm in question was that of Messrs. Short Brothers, Limited, a well-known family of aeronauts, whose activities had long been associated with the manufacture of balloons, and, during later years, with the seaplane bearing their name, which has become an accepted unit of the Navy. The airship yard which they laid out at Cardington is undoubtedly the finest and best equipped in the world. It is doubtful whether even the Zeppelin interests in Germany can point to such an excellently and beautifully equipped organisation. It is self-contained in the fullest sense of the word, and might very appositely be described as a miniature Portsmouth or Devonport dockyard, only devoted to the needs of the naval dreadnoughts of the air.

Certainly it would be difficult to find a more suitable site than that offered at Cardington. It lies in the centre of the broad-floored Great Ouse valley, in one of the most picturesque stretches of rural England. The country is fairly wooded, as is only to be expected in such an agricultural country, although the actual site selected for the "yard" is strikingly open. Consequently, it offers all that elbow-room which is so vital to the easy and safe manœuvring of these

craft, while the facilities for getting away quickly and easily, as well as safe and prompt return, no matter in what direction the wind may be blowing, leave nothing to be desired. The valley itself is rimmed on either hand by a distant low ridge of hills which serve as an excellent natural breakwind. The buildings, extensive in character, have been laid out along accepted scientific factory planning principles, enabling work incidental to the fabrication of all and every part, from the largest to the smallest, to be conducted to the highest degree of efficiency, while adequate space is provided both for the erection of the huge craft and their accommodation when completed, pending acceptance trials, when, of course, they are drafted to their appointed stations. By the time the equipment of the yard was finished approximately £500,000 had been expended, and some idea of the constructional facilities which have been provided may be gathered from the fact that the works are able to produce four monster craft a year, and afford employment for 4,000 men and women.

It is not until one has come to close quarters with the Cardington airship construction yard that one is able to realise fully the immense tract of ground which is essential for the conduct of such work. But it may be brought home very convincingly by reference to one item—the dock in which the ships are built and moored. Obviously, this must be adequate to receive the largest vessel, and at the same time allow extensions to be made to keep pace with the development in the dimensions of such craft. The Cardington dock will carry a 700-footer with ease. But the provision of the dock does not complete the scheme. The vessel has to be manœuvred outside this shelter after being brought out or before being taken into the dock. At least twice as much space is required outside the shed as within it. But more

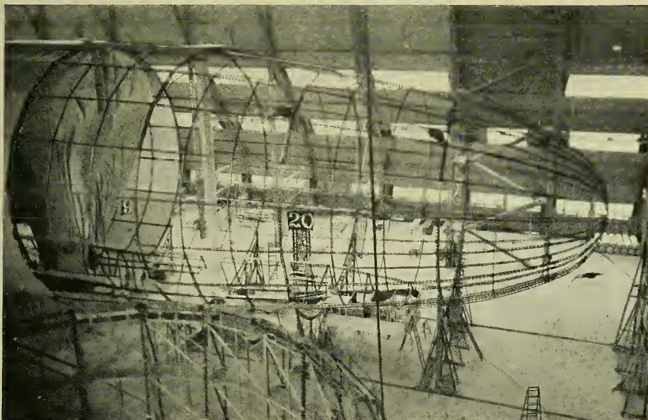
than this has to be assured. The dock is double-ended; that is to say, it can be opened at either end, because the airship must always be manœuvred nose to the wind. Consequently, she must always be manœuvred while on the ground upon the most favourable approach to the dock. In these circumstances, therefore, it will be seen that while the dock itself may measure say 800 feet in length, an area of ground of equal length must be provided at either end thereof, so that the dock space really represents a continuous length of 2,400 feet, or nearly half a mile. When we get the 1,200 and 1,500 feet airships, which we are assured will be at no distant date, the walk from the outer end of one approach through the dock to the extremity of the other approach will be a constitutional indeed, seeing that it will be approximately one mile, the actual length of each approach being somewhat longer than that of the dock itself.

To grasp fully the lay-out of a Zeppelin dock, it is necessary to refer to the illustration facing page 176. The actual dock itself is represented by the shed proper, while there is an approach at either end. We will suppose that the building runs due north and south. The airship is coming in from her voyage, and is approaching the dock. The wind is blowing from the north. The dirigible manœuvres until she has brought her nose dead on to the wind, and is within reach of the approach on the south side of the dock, the doors of which are opened in readiness to receive her. The engines are kept running at sufficient speed to offset the wind, so that she remains poised in the air. The landing ropes are dropped and are caught up by the landing crew. Slowly the airship is brought to earth and is warped on to the approach. Once she touches the ground she is being held in relatively still air, because the shed itself acts as a windbreak or screen

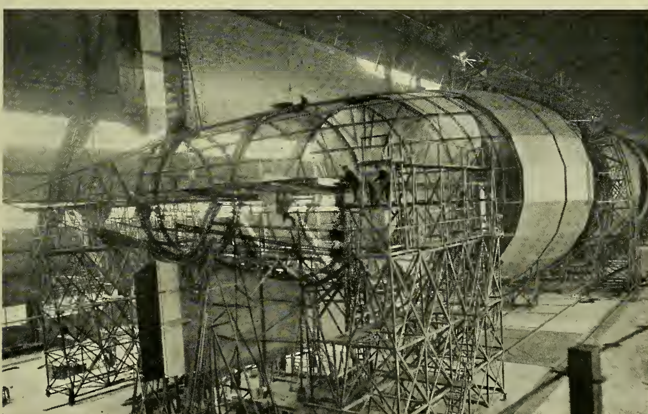
against the wind blowing from the north. So the airship can be worked into her shed without danger from the wind being incurred. If the wind be blowing from the south, she would be landed on the approach, on the northern side of the dock, and so secure the advantage of the still air lying on the lee side or north end of the dock.

But the wind may be blowing across the landing ground—from east to west, or vice versa. In either event the dock building, as it runs north and south, cannot extend any protection against the wind. But this condition is fully met. On the windward side of the approach is built a massive wooden screen or windbreak, identical in length and height with the dimensions of the airship. The other approach has a similar screen, but on the opposite side. Consequently, if an easterly wind be blowing at the time of landing, the airship would make for the one approach, and when brought to earth would be completely sheltered from the side wind by the screen, allowing warping into dock to be carried out without difficulty. In the event of the wind blowing from the west, she would favour the other approach, to obtain the protection offered by the screen.

In describing the lay-out of the dock and its approaches, together with the influence of the wind upon landing, I have purposely selected the simplest form of winds, i.e. those blowing directly end-on or at right-angles to the dock. Diagonal winds complicate the situation to an appreciable degree, and sometimes render the selection of most suitable approach somewhat difficult; but in actual commercial practice it will probably be very rare for a ship to go into dock, certainly not after each voyage, but only for overhaul. In the latter event it would generally be possible to take full advantage of a favourable wind. But, if open mooring be practised, as is



Bow view of the metallic skeleton, showing how the longitudinal girders are shaped and connected to form the rounded nose.



Photos. by courtesy of Messrs. Short Bros., Limited.

Completing the stern, showing the portable stage whereby the workmen are given command of the vessel at different working levels. This illustration shows work in progress upon the elevators.

A BRITISH DIRIGIBLE IN THE MAKING

advocated, and this be provided in close proximity to the dock, then the area of territory which will be required will need to be still further increased. I have purposely described the docking facilities at length to emphasise the relatively large expanse of territory which must be acquired for the establishment of a Zeppelin construction yard. It is scarcely possible to have too much elbow-room. Should the dock be distinct from the erecting covered-in slip, then still more ground will be indispensable. Zeppelin was brought face to face with these docking difficulties in connection with his work, but he sought to obviate them by utilising a floating dock upon Lake Constance, moored at one end, which could be swung round to the most favourable position according to the wind. But in this country we have no suitable inland sheet of water of sufficient size to permit the adoption of this system. In any event, a floating dock would not completely meet the situation. The building dock must be established on dry land, contiguous to the workshops, and must be provided with adequate landing facilities to permit the vessel to be moved in and out during her preliminary trials, it being only advisable to transfer her to the possibly distant floating dock when the necessity of being close to the workshops no longer obtains.

But the dock, while representing the largest individual building in a monster dirigible "yard," is not the only example of a big work in this connection. All the buildings have to be of apparently abnormal dimensions, that is, compared with the facilities requisite for similar work of other industrial undertakings, from the simple fact that all the integral or component parts of the airship are of relatively large dimensions. Consequently, there is a spaciousness about the airship factory which is not to be found in any

other realm of endeavour, with the solitary exception of the shipyard. This is not surprising, because the building of an airship and an ocean liner have much in common. Many of the integral parts of a steamship are of impressive dimensions, requiring liberal space for their movement. A similar state of things is encountered in the aircraft building establishment.

The monster dirigible may be briefly described as a fabrication of aluminium alloy girders, wooden beams, wire, and fabric. In the skeleton form it appears to be an exceedingly slender assembly of metal, wood, and wire, one and all of which have been reduced to the lightest possible proportions. It absolutely fails to impress one with that wonderful degree of strength and massivity which it possesses in its final form. When the hull of the *Mauretania* was sent down the launching ways it represented a dead weight of 16,800 tons, and she is 790 feet long This is equal to about 21¼ tons for each foot of her length. H.M.A. R32, built at Cardington, is 615 feet over all, and when she left her building slip she weighed 30½ tons, which is equivalent, for each foot of her length, to approximately 110 lbs! Surely the limit of strength with lightness must have been attained.

How is it possible to secure such a degree of strength as is required to battle against a high wind for such an insignificant weight? To obtain a convincing answer to this interrogation it is necessary to pass behind the scenes; to follow the fabrication of the parts at close quarters; to venture on to the scaffold where assembly takes place. It is also requisite to observe the shape of the hull, seeing that the design adopted favours the utilisation of extremely light parts by reducing the resistance offered to the air to the minimum.

In profile the dirigible presents an approximate stream line. The nose is conical, or fish-headed, in shape, the

central portion is a parallel, while the stern has a tapered form, terminating virtually in a pencil point. Externally the body is not truly circular in section, but is polygonal, the polygon having twenty sides or faces. The whole of the framework is built up on the triangular girder system, which really explains why the structure, while admittedly so light, has yet such pronounced strength. The system upon which the girders themselves are built also contributes to the degree of lightness attained, a factor which is accentuated by the use of an exceedingly light, but tough, aluminium-alloy having a high tensile strain.

The alloy is prepared upon the spot, the precise proportion of the aluminium and other constituents having been determined by the chemists in the laboratory. The mixed molten metal is poured into moulds, and when cool presents slabs about 30 by 15 inches, by 1½ to 2 inches in thickness. It is now submitted to a prolonged and intricate manufacturing process, involving repeated heating in furnaces, the temperature of which is critically controlled by delicate and extremely sensitive scientific thermometers, and passage through heavy rolling machines. In this manner the texture of the alloy undergoes a startling change, the successive processes knitting the molecules of metal more and more tightly together, and at the same time rolling the slabs out into big sheets.

By the time the rolling and heating have been completed, the cumbrous, dull-looking, squat slab of metal has been transformed into a large sheet, having the lustre of aluminium, resistant to oxidation, and although no thicker than a visiting card, possessed of the toughness and strength of high tensile steel. Despite its thinness, the metal refuses to bend, except under great strain, whereas a sheet of aluminium

of equal thickness would be as flexible as cardboard. But though remarkably stiff and tough it is far from being brittle, and will withstand appreciable twisting and doubling before breaking.

The sheets are cut into narrow strips of varying dimensions. The wider strips are passed through a machine which transforms them into channels of wide ⊔-section, while the narrower and thinner strips are passed through presses which stamp them out into small, specially shaped lengths of a few inches.

The smaller pieces are stamped out by the million, a whole battery of machines, operated by girls, being kept at this work from morning to night. These small pieces form the bracing or lacing of the triangular girders. After being pressed to shape they are passed through drilling machines to receive small holes, jigs being utilised to facilitate and expedite the task, as well as to bring the respective holes precisely in the designed places to ensure that accuracy of fit which is so vital.

The assembling of the girder then proceeds, and this is work which is also carried out by girls, the character of the task being eminently adapted to small and nimble fingers. The channel-piece, about ten feet in length, is placed in a jig, and the cross-lacing pieces secured thereto. In the case of the airship every part is riveted up, whereas, with the aeroplane, as related elsewhere, similar work is welded by means of the oxy-acetylene flame.

As may be imagined, the manufacture of the triangular girders for the dirigible is intricate, and requires to be conducted with extreme skill, especially in screwing the nuts right home; but practice has enabled the girls to carry out this work with amazing speed and dexterity. When each side

of the triangle has been laced in this manner, the three faces are bolted together to complete the triangular girder, which is equilateral in section △.

In the assembled girder form, although the integral parts are of such slim dimensions, the semblance of strength becomes apparent. To satisfy one's-self upon this point, it is only necessary to rest the ends of a 10-feet length of complete girder upon two stools and to sit upon the girder in the centre. One may turn the scale at 200 lbs., and may jump and jolt as much as one pleases, but the girder will give no perceptible sign of deflection. Yet that completed girder can be picked up and balanced by the little finger!

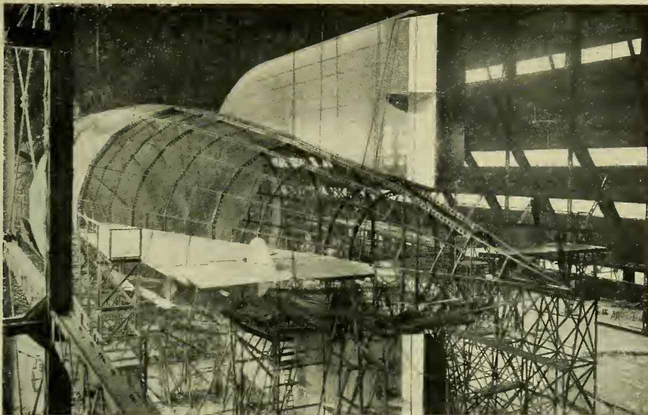
When one learns that it weighs scarcely 10 lbs—somewhat less than 1 lb. per foot—one is amazed at its enormous degree of strength. It is then that one commences to realise why it is the dirigible possesses such marvellous strength as to be able to drive its way against a 40-mile wind without buckling up concertina fashion. Why, the whole length of a continuous longitudinal girder of this design, although 615 feet in length, worked into the hull of R32, weighs only about 480 lbs.!

The construction dock recalls nothing so much as a shipyard in which an ocean greyhound is gradually being fashioned. From the roof to the ground represents a fall of 200 feet. Loftiness in the building is essential, because the maximum diameter of the R32, which was built in these shops, is 65½ feet, while that of her consort R37, which was on the stocks at the time of my visit, is even greater. Ample head-room is essential for a further reason. When the vessel is complete and ready for her trials, she rides at her moorings at a higher level than is the case when resting on the slip, while roof space is necessary to facilitate free manœuvring

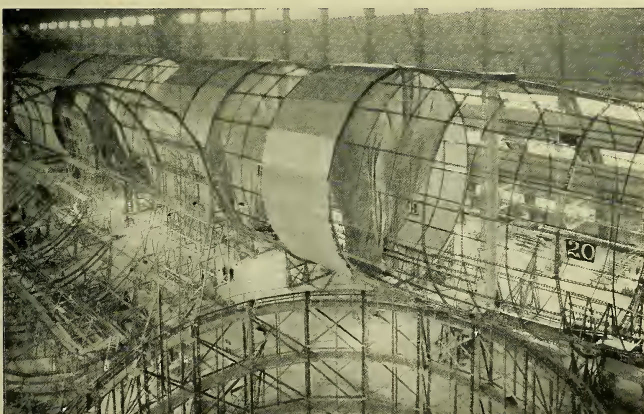
within the dock, otherwise the outer covering of fabric might receive damage during the operation.

Running from end to end of the shop, and a few feet below the ridge of the roof, is a narrow overhead platform where the more clear-headed workmen find a perilous foothold for carrying out erecting work upon the top of the airship. The side scaffolding is mobile, comprising staging, mounted on trolley wheels, allowing the men to work at varying levels to a point well above the diameter of the ship. Another erecting stage is so formed as to straddle the vessel's back, so that any point upon the upper half may be reached. These erecting facilities are supplemented by a kind of gridiron in the roof, with ropes and pulleys, whereby overhead lifting and support can be extended to any desired degree. What may be described as the scientific rapid construction of these large aircraft has demanded the elaboration of special appliances to assist in the work—appliances which do not find their counterpart in any other field of industry. In the shipyard, both in open and covered slips, cranes are freely employed; but these would be superfluous in the airship dock, for the simple reason that the weights to be handled are so trifling. Some of the parts may be cumbersome, but in no instance is the weight to be moved likely to exceed a few hundred pounds.

The hull itself rests upon a cradle, similar to that which supports a liner in the making upon its slip. In so far as the airship itself is concerned, construction is complicated from the simple fact that no array of parts secures any degree of rigidity until it has been connected up to the whole. What may be described as a general looseness and lack of solidity obtains, which is essentially due to the lightness of the component parts. For instance, a ring, or rather complete



Stern of dirigible ready to receive outer covering of fabric, with vertical fin, rudders and elevators finished and placed in position.



Photos. by courtesy of Messrs. Short Bros., Limited.

General view showing central section of one airship completed, gas bags being set, and outer covering applied, and a second vessel in course of erection.

BUILDING A BRITISH DIRIGIBLE AT THE CARDINGTON AIRSHIP FACTORY

polygon of frames, is about as stable as a similar, though miniature, piece of work executed in matches, when considered merely as a ring. There is a tendency to whip, twist, and bend under its own weight, which is a little over a hundredweight, although the frame is nearly 70 feet across. In these circumstances, therefore, it will be seen that construction has to be carried out with supreme care and in accordance with rigid principles which have been scientifically determined by the technical staff; otherwise, a collapse is almost inevitable. Moreover, the task of "lining-up"—that is, the correct alignment of every piece—is a delicate operation, as well as one of distinct magnitude. Of course, skill born of experience is of decisive assistance, but even then there can be no departure from the methods which have been introduced by the General Manager, who is the presiding genius of construction, to produce a sound engineering job.

The backbone of the airship comprises a keel. This is built up in the form of an equilateral triangle from girders of the design already described, which are disposed at each corner of this triangle and elaborately cross-braced to give the keel solidity and rigidity. This triangular structure is called upon to bear an appreciable proportion of the many strains imposed, notably of what might be called the "live" weights, such as petrol, water-ballast, and other impedimenta, which are distributed evenly along the keel to relieve the hull as much as possible from all undue strains. The base of this triangle constitutes the floor of the alleyway or tunnel affording inter-communication between the various parts of the ship, the engine gondolas, fuel tanks, and even the gas-bags or the top of the ship itself, a vertical shaft extending from the tunnel to the top of the vessel.

The rings of main frames are completed in the horizontal position upon the floor of the shop. This method assures a firm and solid base for erection, so that when finished the ring is not likely to be out of truth. When the ring has been completed, it is lifted intact, and, by means of the overhead rope and pulley tackle, is swung and lowered bodily into position. This, in itself, is a task calling for care and skill, because, unless adequate support be extended, the ring will suffer deformation imperilling rigidity by working at the connections, or bending. The actual erection commences from the centre, the amidships main frame being first set in position and bolted up, lined-up, and rigidly braced. Once this has been set, erection can be pursued simultaneously on both sides thereof towards the stern and stem respectively. The framework itself comprises the polygonal rings of girders and the longitudinal girders. The first-named are divided into two classes, these being the main frames and lighter intermediate frames. The former are set about 30 feet apart, accurate shape being rigidly preserved by means of radial wires carried to a centre ring, and may be said to form the cell in which the gas-bag is placed. At intervals of 10 feet between each of these main frames a ring of intermediate girders is introduced. These are of lighter section, and they are not wired, their function being to assist in keeping the ship rigid, and to absorb the difference in tensions in the diagonal wires.

The longitudinal triangular girders run from stem to stem, and they cross each ring of frames at the point where the sections of the polygonal girders are connected up, and are securely fastened thereto. The complete ship carries twenty of these longitudinal girders disposed 10 feet apart around its circumference, and they are braced together by diagonal

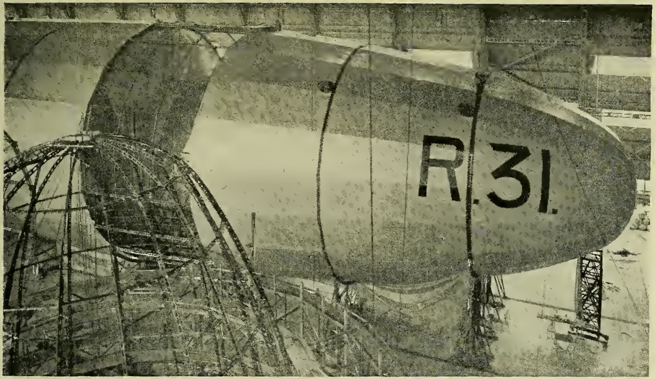
cross-wires, the purpose of which is to take up the shearing forces due to the ship as a beam, and also to take up the gas pressure due to the upward lift of the gas, which is considerable.

The nose of the ship is built in a different manner. The ring of main frames, from which the tapering of the bow commences, is laid upon the floor. To this the lengths of longitudinals extending to the succeeding frame are bolted and temporarily supported by scaffolding. The succeeding frame is then laid in position, the further lengths of longitudinals introduced, and the next ring of frames set, the operation being continued until the prow is completed. This method of erecting the forward section as a distinct entity is simpler, quicker, and secures greater accuracy than if the system incidental to the remainder of the ship were followed. After the first ring of main frames has been laid on the ground, it is easy to determine the central point the ring describes, and exactly over which must come the central point of the prow. It must be remembered that as the nose of the ship is approached, the rings of frames decrease in diameter, and it would be a somewhat delicate matter to line up this section, bringing the central point of the nose of the ship upon the longitudinal axis of the vessel were individual setting *in situ* followed. By building the prow complete upon the floor, lining-up is facilitated. A plumb-line attached to the central point of the nose will speedily prove whether alignment is perfect, because the bob should hang immediately over the spot on the floor constituting the centre of the bottom ring-frame. The airship is not fitted with a single casting forming the stem as is the case with the steamship, the actual nose being formed of triangular girders, curved to shape and bolted together. The prow completed, it is picked

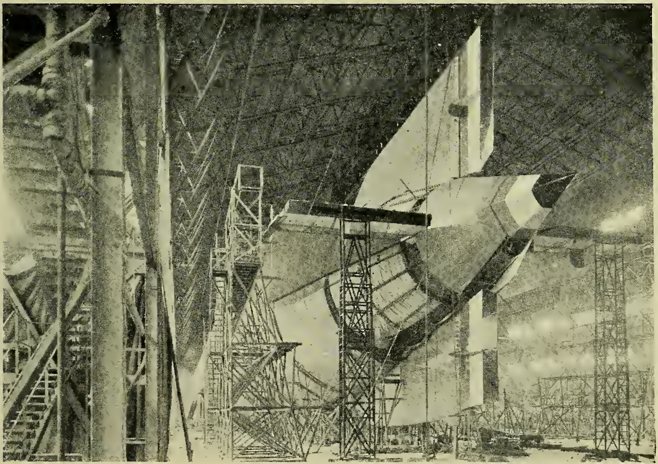
up bodily by the overhead tackle, turned over on its side, and then swung over, bringing what was the base ring of main frames into line with the hull of the main ship. It is lined-up and quickly bolted into position, cradles being introduced at the desired points to prevent sagging strains until the junction has been made and diagonal and other bracing wires have been set.

The stern is not such a difficult piece of work. Here the longitudinal girders converging in conformity with the tapered aft shape of the vessel terminate in a circular observation station. A person can stand there with only just his head projecting, and there is a magnificent and completely uninterrupted view astern. Even the sense of wind, or the rush of air displaced by the vessel and tearing along its sides is lost, because, at the top, the line of the hull is slightly interrupted, and the head can occupy this space, the air rushing over without being felt in the slightest degree. The "pulpit," as this post is facetiously called, is one of the most popular coigns of vantage on the whole vessel, and certainly cannot be rivalled as a view point.

As the hull of the vessel is completed, and it creeps forward to either end—in segments, as it were, each of which is finished—the gas-bags are introduced. These bags occupy the space between each pair of main frames. No partitions or walls of fabric are introduced to form a cell and to provide a surface against which the distended fabric can rest; but there is a complex lacing of wires, forming, from its intricacy, virtually a wire netting, which serves a similar purpose. The bags do not fill the whole of the volume of the "cell," because a clear space is left between the inflated gas-bag and the outer cover to keep the temperature in the gas-bags at as constant a level as possible. The principle is the same as the double-



Completing the prow, showing forward building cradle. At left is forward end of second vessel completed, showing system of building vertically from the floor. This section is picked up, turned over on its side, and then bolted to central section of the vessel.



Photos. by courtesy of Messrs. Short Bros , Limited.

Stern completed. This photo. graphically illustrates the cruciform empennage, sharply pointed stern, erecting scaffolding mounted on wheels, as well as the immense size of the dock required to build vessels of this character.

HOW A BRITISH DIRIGIBLE IS BUILT

canvas-roofed tent with an airspace between. It is the circulation of the air between the two roof-layers which keeps the temperature within the tent equable, preventing the heat radiation from the other covering. Maintenance of an equable temperature of the gas within the bags is of vital importance, as it tends to mitigate expansion and contraction of the gas likely to arise from this cause.

The gas-bags are made of a single-ply cotton fabric, lined with gold-beater's skin, the finest material for the purpose, and that which offers the greatest resistance to the permeating or diffusing action of hydrogen, and varnished. In the R32 there are twenty-one compartments, each of which carries one of these gas-bags, so that practically the whole of the interior of the hull, from stem to stern, is filled with gas. Each gas-bag is fitted with two valves—manœuvring and automatic respectively. The manœuvring valve is fitted into the top of the bag, and is operated from the control car when it is desired to alter the trim of the ship, thus being manually actuated. The automatic valve, on the other hand, as its name implies, is independent of any control, and is introduced to prevent the gas-bag being ripped by the internal pressure of the expanding gas rising above the elastic limit of the fabric. This valve is placed in the bottom of the gas-bag, just above the corridor running through the triangular lattice girder alleyway. It is set to blow off at about 3 millimetres water pressure. From the valve to the top of the ship extends a circular fabric shaft or trunk, and this acts as the exhaust from the gas-bags to the outer air when the valve "blows off," thus carrying the hydrogen away immediately, and discharging it into the air at a point well away from the engines. It is a safety measure, but one which is invaluable when one recalls the extremely dangerous character

of hydrogen, and its liability to explode when combined with air.

At the stern are mounted the fins, rudders, and elevators. They are cruciform in shape, and consist of a light framework of wooden girders covered with doped and varnished fabric. They probably represent the heaviest individual part of the whole vessel. The fins serve to maintain the vessel upon an even keel, frustrating any tendency to roll or pitch, thus acting in the same way as the bilge keels of a steamship. The elevators are for altering the course in the vertical plane, elevation causing the nose of the vessel to ascend, while depression exercises the opposite effect. The rudder is distinctly imposing, being attached to both the upper and lower vertical fins, and has a total active length of about 20 feet. Of course, both elevator and rudder are controlled from the wheels mounted in the navigating car set at the opposite end of the ship.

When the skeleton has been completed, it is completely enveloped in an outer cover. This skin is made from cotton fabric, doped and varnished. It is stretched over the framework in sections, and thus produces a smooth polished surface, reducing skin friction, as the vessel moves through the air, to the minimum. This outer covering possesses no gas-retaining qualities as is sometimes imagined; it merely gives the desired external form and contour to the ship, though, of course, it does protect the gas-bags within from the ravages of wind and weather.

The control of the vessel is effected from a cabin projecting from, and on a line with, the triangular-girder keel, being set at the point where this part rises to form the nose of the airship. Here are arranged the various instruments necessary for the navigation of the craft—compasses, barometer, alti-

meter, helm, and so forth—as well as a complete telephone exchange communicating with various working parts of the airship, including the gondolas carrying the engines. In the case of the naval vessels, a gun position is provided on top of the airship forward; communication between this and the navigating car or bridge is maintained by means of a voice pipe. Under peace conditions this position will not be required for its designed duty, although it will probably be maintained as an observation post. The wireless cabin is also placed in this car.

The engines are mounted in gondolas. These are small and compact structures, the framework being of the metallic latticed triangular girders. In the case of the R32 there are five of these gondolas, all of which are slung under the ship. The forward and amidship cars are disposed in pairs, while that at the stern is a single unit. Each, complete with the whole of its equipment, weighs less than one ton, and the method of suspension, by a few slender-looking wires, at first arouses misgivings; but this disappears when one is informed that these wires are capable of carrying forty or more times the strain to which they are ever likely to be subjected. Each gondola of the vessel in question carries a 300 horse-power Rolls-Royce engine, coupled direct to a propeller 17 feet in diameter. The engines disposed amidships are provided with reversing gear, to permit driving astern, and for manœuvring purposes; the other units drive in the one direction only—forward. Access to the gondolas is by means of a short rope ladder and man-hole, the cars being completely enclosed to secure protection from weather, but fitted with safety glass windows.

Before closing this description of a monster dirigible in the making, a few particulars of the R32 may be interest-

ing. This, and the sister ship, R31, are the product of the Cardington works, while at the time of my visit a third and much larger vessel, R38, was well under way. While R32 is smaller than both R33 and R34, she is maintained to be a superior type of vessel, and certainly has a higher turn of speed. She is admitted to be largely of an experimental nature, and it is anticipated that when she has settled down to her work she will have a speed ranging from 65 to 70 miles per hour. She thus ranks as the fastest ship at present in service.

Her principal dimensions are:

Length	615 feet
Maximum diameter	65½ ,,
Capacity	1,550,000 cubic feet
Total lift	47 tons
Disposable lift	16½ ,,
Total brake horse-power	1,500
Endurance at two-thirds full power ...	2,200 nautical miles

While the Government is to be congratulated upon having supported the finest and best equipped dirigible airship construction yard in the country, if not in the world, is it not a matter for regret that private enterprise should suffer such a severe set-back at the very moment when it is most urgently required in the interests of the nation? The firm which has carried out the work of laying out and equipping the yard, as well as the erection of three of our monster airships, has acquired experience and knowledge of far-reaching value and significance which are in danger of being completely lost. As narrated in another chapter, Messrs. Short Brothers, Limited, had completed the designs for a transatlantic liner in the strictest sense of the word. The completion of this

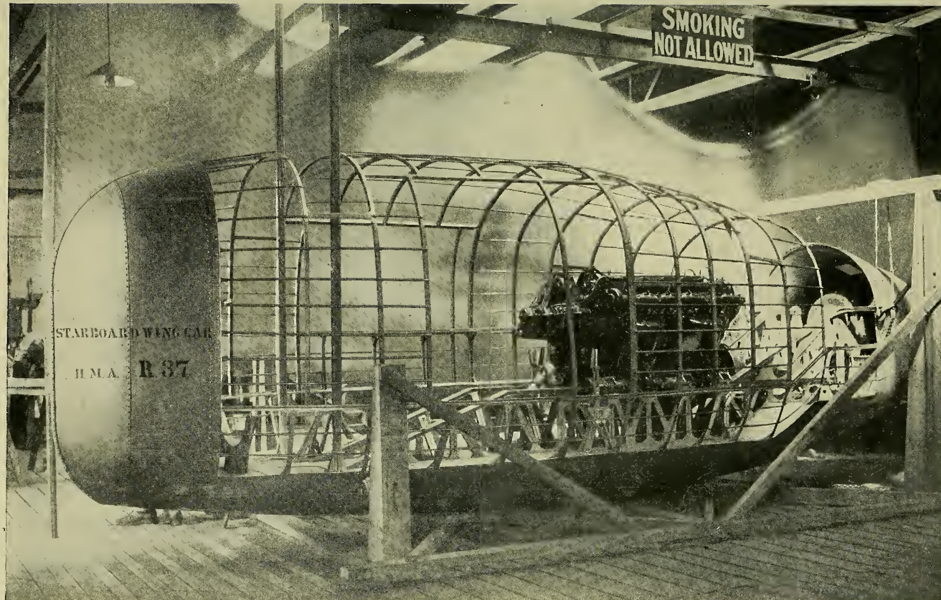
vessel in the near future would undoubtedly have been fulfilled, and doubtless would have gone a long way towards the establishment of a regular aerial express airship service between England and the United States of America. This proposal has now been indefinitely postponed. Official uncertainty has accomplished one regrettable result. It has disrupted the organisation which had been perfected, and has scattered the "live wires" who were enthusiastic in their efforts to establish a commercial aerial service upon a firm footing, and who, from their capacity and knowledge, were competent to carry the work to successful fulfilment.

CHAPTER X

THE SEAPLANE

WHILE the aeroplane has achieved such remarkable performances, both in cross-country and trans-marine service, it is not adapted to sea-duty. When the negotiation of immense stretches of water are involved, its use in such service is decidedly perilous. This fact was expressed very emphatically by Sir John Alcock after his transatlantic flight. He fully recognised that had he been forced to the water he could never have got into the air again, because his craft, designed for land duty, was deficient in the facilities for gaining the necessary flying speed.

The reason is obvious. The aeroplane is equipped with an undercarriage fitted with wheels, and so is able to run or "taxi" along the ground to obtain the requisite independent speed necessary to climb into the air, while in descent the land provides the means of absorbing the momentum possessed by the machine after it has lost its flying speed. When it is remembered that the landing speed of the aeroplane varies between thirty-five and fifty-five miles an hour—that is to say, that it is travelling at these speeds when it touches the ground—it will be seen that it must be extended a fairly long stretch of level land along which to coast and in which to pull up. Some of the German planes, and even those which we have designed for especial duty, upon striking the ground will travel along the latter for three



WING CAR OR ENGINE GONDOLA FOR H.M.A. *R. 37*

Showing the system of construction and installation of Sunbeam "Cossack" aeromotor. This photograph conveys a graphic idea of the roominess of an airship's engine-room.

miles or so before coming to a standstill. For such a craft to hit the water upon a forced descent is to court instant disaster, because, naturally, the water can offer no stable surface to the wheels of the machine.

Consequently, we find special machines built for sea service. In their general lines, so far as the wings and body are concerned, they may not differ markedly from the aeroplane; but the undercarriage, instead of being equipped with wheels, is furnished with what appear to be big, oversized boots, or floats. These are not only capable of supporting the machine when at rest, but are so designed that for ascent they are able to skim over the surface of the water until the machine, having notched the requisite flying speed, can rise into the air. Similarly, in descent, they skim the water, and the latter, by virtue of the resistance it offers, acts really as a brake, and so brings the machine to rest. The body of the aquatic flying machine may even be equipped with a body more closely resembling an actual boat and a highly-poised tail, forming in very truth a flying boat, and which, when moving over the water, recalls the flying fish.

During the war the seaplanes proved an invaluable adjunct to the Navy, more particularly for scouting, reconnoitring, patrolling, and especially for chasing submarines. As a matter of fact, in company with the small and light non-rigid airship, colloquially known as the "blimp," it became a veritable scourge to the underwater assassins. When these aerial craft were in the vicinity, the submarine either scuttled to a safe lair, or sank to the sea-bed to lie low until the bird of bombs and depth charges had passed on.

The flying machine adapted to marine duty aroused less serious interest in these islands than the aeroplane, which, in view of our insular situation and the magnitude of our water-

borne traffic, is certainly somewhat remarkable and difficult to comprehend. It did not appear to appeal to popular or technical imagination in any way. Indeed, interest was so low that it was only through the dogged enterprise of one firm, Messrs. Short Brothers, of Rochester, that this phase of activity was taken up. They commenced operations some time before the war, and the all-round excellence of design and construction of their machines, combined with sustained high level of performance, attracted the attention of the Admiralty, which certainly did extend an appreciable measure of practical encouragement and support.

It was the Short seaplane which first brought home to the Germans what they might expect to receive from Naval Britain in the air if, and when, we felt so minded. The inhabitants of Cuxhaven are never likely to forget the terror and destruction our craft of this type wrought on Christmas Day, 1914, in the raid made by seven machines fitted with 200 horse-power aeromotors, upon this naval base at the mouth of the Elbe, the full effects of which have never been communicated to the world at large. Again, in the Battle of Jutland, the seaplanes fulfilled work of a far-reaching and vital character. But these machines never loomed prominently in the limelight, for the simple reason that, like the Navy, they were denied the opportunity to demonstrate their real value. Nevertheless, they accomplished superhuman work, patrolling the coasts regularly night and day in all weathers, pushing far out to sea in quest of their prey—the submarine and other subtle Teuton craft—and by acting as eyes and ears to the Grand Fleet, brought home to the enemy the incontestable fact that his vaunted navy was far safer behind a dense barrier of minefields and under guns of impregnable fortifications than upon the expanse of the open

North Sea. We know that the Navy never talks, and the aviation branch appears to have become imbued with the self-same characteristic trait of silence concerning the exploits and achievements of the seaplanes.

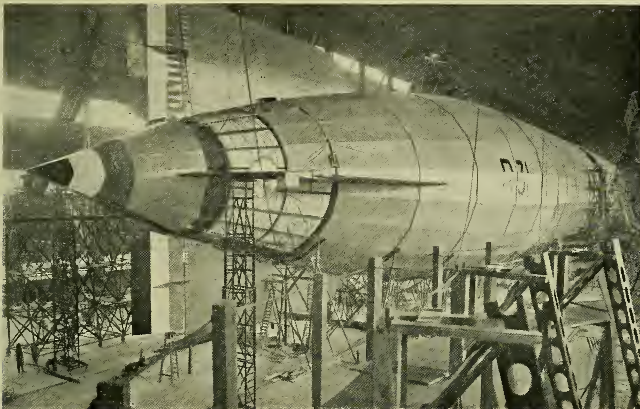
What of the seaplane in commerce? Is it of any value to business? Such questions are inevitable, especially in view of the little knowledge concerning their behaviour and record of service communicated to the outside world. We know scarcely anything of their development, and for this reason are disposed to consider the aeroplane, which was certainly produced in far greater numbers, as the incontestable flying machine for commercial activity in the future.

But this dependence upon the one craft is erroneous. Each has its specific field of service, and the range of duty is far more sharply defined than may be imagined, while it is not too much to assert that the aeroplane, just because it is more familiar to the public, is being applied to services of transportation for which it is less suited than the seaplane. The last-named has this one great advantage over its contemporary: It does not demand a specially-selected and laid-out stretch of level country from which to ascend or upon which to alight. It is often difficult to secure an attractive enough site for an aerodrome sufficiently contiguous to the centre which it is desired to serve. This is especially notable in regard to our coastal towns and cities, with the exception of those situate between the Thames and the Wash. On the other hand, the seaplane can settle anywhere upon the water, be it a small harbour or even the open sea. Again, it must also be borne in mind that the air-line by sea is often the shortest route between two coastal points, while, in the majority of instances, if no convenient harbour be available, there is

an estuary, roadstead, or loch affording ample ascensional and landing facilities for the seaplane, and within easy reach of the centre it is designed to link up.

As the virtues of the seaplane become more widely appreciated, it is only logical to anticipate a decided commercial development of this machine, more particularly in regard to the establishment of new coastal routes. Of course, for the opening-up of new and sparsely settled countries, possessed of excellent waterways and inland seas, it has far-reaching possibilities. What can be done in this direction was brought home very convincingly in the course of the naval operations upon Lake Tanganyika during the African phase of the war. The establishment of adequate seaplane passenger, light parcels, and mail services upon such stretches of water as this, as well as the Nile, bringing the scattered settlements more closely into touch, not only with one another, but also with the terminals of railways extending to the coast, would facilitate and increase the pace of development and trade expansion. Even around our own coasts there are many large islands which, to-day, are lagging from lack of connecting services with the mainland, and the limited needs of which could be efficiently fulfilled by means of the seaplane.

The Short seaplane, as proposed for commercial operations, is at present being presented in three models. One, the sporting Short, is one which should make wide appeal, especially to the lover of the water revelling in boating and yachting, but who, at the same time, is attracted to the realm of the air over the water. This machine is more particularly adapted to general service because, in common with all craft built at the Rochester yards of this company, it has the folding wings which were introduced by these brothers long



General view of the vessel from the stern showing pointed after end.

Photos. by courtesy of Messrs. Short Bros., Limited.

Trial flight of the airship.

THE DIRIGIBLE ON THE STOCKS AND IN THE AIR

before the outbreak of war. This enables the wings to be folded back to rest against the body, after the manner of those of the bird or insect, so that the space required to house the machine is very materially reduced. All that is required is to withdraw or insert a pin or bolt at the point where the main front spars of each wing connect up to the fuselage, to fold, or to secure the wing in the outstretched position, as the case may be, the rear spars of the wings being hinged in a special manner to the fuselage.

The tip-to-tip wing span, when outstretched, of the sporting Short seaplane is 44 feet, while the over-all width, when the wings are doubled back, is only 15 feet. The total wing surface is 500 square feet, length over all 33 feet, and the height 12 feet. Thus this machine can easily be garaged in a building which need only be of light construction, measuring 40 feet long by 20 feet wide and 15 feet in height. It is fitted with a 160 horse-power 6-cylinder vertical Beardmore aeromotor, and carries tanks having a capacity of 35 gallons of petrol, while provision for 3 gallons of lubricating oil is made. The machine is able to climb to a height of 10,000 feet in 35 minutes, and its maximum speed is 83 miles per hour. The radius of action upon the single fuel charge is 270 miles or 3 hours' flight with two passengers up, in addition to the pilot. The landing speed is between 30 and 45 miles an hour.

Running costs of this machine should be relatively low, the Beardmore engine being economical in fuel. As will be seen, the petrol consumption ranges from 12 to 15 gallons an hour, according to speed. In the empty condition, the machine weighs 2,095 lb., and in running order, ready for flight, with passengers aboard, its weight is 3,100 lb., the difference of 1,005 lb. being made up as follows:

Petrol	255	lb.
Oil	30	,,
Water	80	,,
Pilot	180	,,
Two passengers (180 lbs. each) ...	360	,,
Total	905	,,
Reserve for baggage	100	,,
Total	1,005	,,

If mails be carried instead of passengers, it is possible to deal with a load of about 460 lb.

From the foregoing, it will be seen that such a machine, while offering the sporting aviator the opportunity to gratify his inclinations, is yet eminently serviceable for the maintenance of communication, at frequent intervals, between somewhat remotely situated islands and the mainland, where either no regular steamship service is maintained, or only at irregular intervals, and the mail service between which is not particularly heavy. It could also be employed for the conveyance of light freight, newspapers, and of special passengers in times of emergency, such as doctors, or even visitors having business connections with the island. From the radius of action it will be seen that intervening sea-gaps up to 200 miles might be bridged in this manner, and such a service would probably prove cheaper than the ordinary steamboat. The latter would not be superseded, but could be confined to the movement of bulkier freight, which must perforcedly be carried at a low rate. It must not be forgotten that there are many outlying islands, not only around Great Britain, but other parts of the world, where no telegraphic communication with the mainland exists, and the community

of which is often cut off from the rest of the world for weeks at a time. With the seaplane such as described above, the feeling of isolation which now prevails could be effectively removed.

Designs for what may be described in every sense of the word as an ocean-going seaplane have also been prepared by Messrs. Short Brothers. This is a huge machine, having a tip-to-tip top wing span of 130 feet, and built throughout of steel, driven by three Rolls-Royce "Condor" engines, each developing 600 horse-power, or a total output of 1,800 horse-power. The maximum speed of this craft is set down at 90 to 100 miles an hour, but the economical cruising speed would be from 40 to 50 miles an hour, and the radius of travel approximately 900 miles upon the single fuel charge.

The most striking feature of this vessel is the arrangement for accommodating the passengers. Instead of building a commodious car into the fuselage, the pontoons are designed to serve as saloons. They are each 60 feet in length, and built of light steel. Although two saloons are in this way provided, there would be no intercommunication. In this manner the perfect balance of the machine, under all conditions, would be maintained; whereas, were the saloons, which are naturally set some distance apart to serve as miniature supporting boats when the machine is at rest, interconnected, allowing free movement from one to the other, equilibrium might be disturbed by all the mobile weight, aggregating some 2,200 lb., being imposed upon one side, from all the travellers collecting in the one saloon.

In this machine every luxury is to be incorporated, so that it may be able to provide in the aerial passenger-carrier the amenities and comforts offered by the ocean-going liner. The roof of each saloon constitutes a promenade deck for consti-

tutionals, or participation in those games which are invariably associated with marine travel. Each saloon is to be provided with a steward and cabin-boy, while the officers and crew are given their special quarters. While high speeds will be possible with this machine, it is not proposed to use them normally, but to favour one which, while more moderate, will be conducive to a higher level of comfort. At the same time an ample margin of power will be held in reserve for use when occasion or emergency so demands.

This will be an ocean-going seaplane in true earnest. It will not need garaging, but will be anchored in open water, after the manner of a vessel lying in a roadstead, possible of being brought alongside the landing stage for embarking or disembarking passengers. Its construction will enable weather to be disregarded, since, beyond the fabric forming the wings, there will be little or nothing liable to deterioration from exposure. Dry-docking for the over-haul and repainting of the bottoms of the hulls of the pontoons will only be necessary at long intervals. The same applies to the wings, which are liable to a certain degree of depreciation from exposure to all weathers and degrees of temperature, but which can readily be maintained at a high level of perfection by the observance of ordinary protective measures, such as are involved in the preservation of certain parts of a ship's superstructure.

Present indications may possibly point to such a vessel being premature, especially in view of its cost, which is set down at £40,000 to £50,000. But the future of commercial aviation is uncertain. It may develop with a rapidity exceeding anticipations, as did the motor-car, once its safety and possibilities become fully realised. So it is well to be prepared, more particularly in view of the fact that the con-

struction of such an aerial liner as I have described will take from twelve to eighteen months under the conditions which at the moment prevail.

Before the aerial liner can materialise, there are many questions which demand settlement. Matters concerning depreciation, running costs, fares, and life of the craft as yet are an unknown quantity. But data bearing upon these vital factors are being gathered. The life of the vessel is one point upon which distinct conflict of opinion prevails; but in the opinion of the seaplane builders of Rochester, and especially in regard to seaplanes, it is stated to be comparable with the life of the steamship so long as skilled attention is bestowed upon upkeep and operation. The structure itself should suffer little or no depreciation, while the parts exposed to deterioration, as, for instance, those of the motor, are capable of renewal. At intervals of twelve to eighteen months it would probably be found necessary to renew the fabric of the wings, but this represents the part of the machine most susceptible to wear and tear. The probability is that the seaplane would not be worn out, but would suffer supersession by larger, heavier, and more luxuriously equipped craft. This is inevitable with the constant march of progress, and the resolve to furnish the travelling public with the latest expressions of ingenuity and design to attract patronage.

A preliminary step towards the realisation of the aerial liner is the Short No. 2, the designs for which have also been prepared. This is a triplane and is much smaller. The wing span, tip-to-tip, is about 100 feet. Accommodation is provided for six or seven passengers, but, in this instance, in a saloon built into the fuselage. The speed will be about 100 miles an hour, the idea being to provide a craft to meet the conditions of an express passenger service. The motor

equipment is to comprise two Rolls-Royce engines of the "Condor" type, each developing 600 horse-power.

One factor reacting against the immediate realisation of the big luxurious seaplane, apart from financial considerations, is the absence of knowledge concerning the personnel which will be required for their control and management. Experience has not been advanced to a stage to enable this point to be determined. In so far as steamship travel is concerned, the regulations have become well standardised, and it may be that the principle there followed will be to a certain extent introduced to the air. In that event the crew, including officers, might easily number from ten to a dozen men. The issue will be governed by the length of the scheduled passage, while, of course, the insurance interests will exercise a prominent voice in the matter. Therefore, although the designs for such craft have been prepared and are ready to be put into construction, a complete revision of the present proposals may be rendered imperative with the accumulation of additional knowledge. Nevertheless, the circumstance that the drawings are ready, and that construction can be put in hand promptly, points to the fact that the enterprising British builders are alert to any possible rapid developments in connection with aerial trans-marine navigation.

CHAPTER XI

HOW THE FLYING MAN FINDS HIS WAY

TO the lay mind, the perennial centre of interest upon the modern flying-machine undoubtedly is the dashboard—the point to which all the nerves of the machine converge—whence its control is effected. This magnetic attraction is by no means confined to the vessel of the air; it applies equally to the footplate of the locomotive, the navigating bridge of the liner, and even to the dashboard of a motor-car, if the latter be freely dotted with weird and strange-looking dials and gauges.

In the case of the flying-machine, however, this interest is decidedly intensified. This is not surprising, seeing that, more particularly so far as the aeroplane is concerned, the ability to travel at will through the air appears to be such a flagrant perversion of the laws of Nature in so far as they affect mankind. The dashboard, of a truth, may be said to represent the brain of the machine, because, from the readings of the various instruments, the man at the wheel is enabled to find his way, and to determine such apparently inscrutable problems as the velocity of the wind, the height at which the machine is travelling, its speed, the angle at which it is inclined—fore and aft as well as laterally—the temperature of the water in his radiators, and the behaviour of his aeromotor; or, should the plane be multi-engined, the individual running of each power unit.

Yet the dashboard is merely one side of the box of tricks. The cockpit itself is an intricate centre of command, bristling as it does with levers, wheels, and switches, from the "joy-stick" to the petrol tap, the rudder bar to the ignition control; the hand-wheel for correcting the trim of the machine to the array of switches lighting the lamps attached to each of the calibrated dials upon the dashboard. In some instances there is a tendency to crowd as many instruments upon this relatively small area as possible, as if the sight of the polished surface of the wood were to be deprecated, and it is this bewildering display of devices which is apt to lead the lay mind to cherish the belief that the control of a flying-machine is one of the most perplexing tasks ever presented to man, and that it is only the privileged few who can ever hope to attain the coveted distinction of pilot. If that feeling were confined to the mastery of the instruments so prominently set out, it would probably be correct, especially when, upon turning to another machine the dashboard appears to be sadly lacking in means of guidance, instrumental assistance having been reduced to an extraordinarily low limit.

Whether the dashboard be elaborately equipped or otherwise is a matter of little moment. It may come as a shock to learn that an appreciable number of pilots never consult one of them, or at least only in a perfunctory manner. Certainly they do not depend upon what this or that dial may say. This is not due to contempt born of familiarity, but because the aviators in question are pilots to the manner born, and appear to be endowed with a sixth or "flying" sense, in addition to the generally accepted faculties of which they must have full possession. They certainly have an uncanny instinctive ability to find their way about in the air, have a remarkable intimate feel of the machine, and will rely far more implicitly

upon their own common-sense and intuitive feelings than be guided by the most perfectly contrived mechanical device. On the other hand, some pilots place unswerving faith in their instruments, and will obey their readings unprotestingly. Such pilots are mechanical, constitute to all intents and purposes an integral part of the machine, and so are disposed to numb their own powers of reasoning and deduction. Too implicit a faith in devices of this character, no matter how beautifully designed or astonishing their degree of precision, is somewhat to be deplored, because even the most faithful of mechanical aids is likely to fail, and if such occur at a critical moment the results are likely to be disastrous.

The compass may be cited as a case in point. Every schoolboy knows that the needle of this instrument points to the earth's magnetic north. It will do so with unswerving allegiance so long as the conditions are favourable. But let a piece of magnetic metal come in close proximity to that needle and it will be deflected from its true path. We know, in so far as steamships are concerned, that the compass has to be adjusted from time to time, especially when the vessel sets out upon its first or trial trip, and a similar correction has to be carried out periodically with the flying-machine's compass, which is not surprising, bearing in mind the amount of ferrous metal which is now worked into these craft.

Notwithstanding the circumstance that the instruments provided may be susceptible to derangement, or under certain conditions give an erroneous record, their provision is indispensable as an auxiliary. This may seem to be a somewhat sweeping assertion, because we know that the mariner is guided almost entirely by his instruments. But the conditions

ruling in the air and upon the ocean are so vastly dissimilar. For instance, a ship could hardly turn upside down without everyone on board becoming apprised of the action. It would not require any erratic behaviour upon the part of the compass to bring home this fact. But in the air, especially in cases of dense fog and thick cloud, as I have narrated in another chapter, an aeroplane is apt to turn clean over without the pilot being aware of the circumstance, and the compass, especially as it is made to-day, continues working quite unconcernedly. At one time the fact that the aeroplane was lying on its back was revealed by the compass card falling off its pivot, and thus becoming useless. But this was construed as a distinct shortcoming because, under war conditions, it was often imperative for the machine to be inverted to fulfil some designed tactical or strategical purpose. When the machine was brought back to its normal position the compass was of no further use until return to the ground. So the compass designer set to work to eliminate this defect. Accordingly, to the modern aeroplane compass it is immaterial whether the machine be travelling normally or upside down; it works equally well in either situation because in the act of inversion the compass-card drops off one pivot on to another. Possibly, to meet commercial conditions, there may be a reversion to the earlier type of compass, close observation of the action of which would tend to warn the pilot in a fog or cloud, presuming he could see the instrument, that his machine was evincing a tendency to turn over.

Obscuration of the instruments mounted upon the dashboard in an open cockpit in thick weather is a serious disability. Often the fog will be so dense as to reduce visibility to a matter of inches—when one cannot see one's hand before one's face. If the navigating and control position be enclosed,

it is possible to thwart the machinations of the fog-fiend to a certain degree—at least maintain sufficient clarity within the cabin to read the instruments from the joy-stick position—although a thick fog is most searching in its character, forcing its way everywhere, as we know full well.

The compass intended for aerial service is of special design. It is what is known as a liquid magnetic instrument, in which the "card" comprises a narrow and light metal ring, pivoted on a vertical axis, and carried in a brass bowl which is filled with the purest alcohol. One side of this bowl is cut away and glazed, as shown in the illustration, to permit the reading to be made. Naturally, in high altitudes, where the air is rarer, expansion takes place, and so the bowl is fitted with a chamber provided with a bubble trap, while the upper portion of this chamber is fitted with tubes and cover for the accommodation of correcting magnets. The "card," a light ring, is enamelled and divided in the usual manner, on either side, the points on the outer side being painted with a radium luminous compound, the markings on the inner side being non-luminous. The card is set or tilted at a slight angle to facilitate reading from the pilot's position.

The instrument is made in a variety of types, according to the machine to which it is to be fitted; but, fundamentally, the principle is the same throughout. Thus there is one type for seaplanes, another for long-distance machines, a third designed for use by observers, and so on, the variation in the main being in detail and dimensions to adapt the instrument for the special range of duty involved. That for the airship is of a distinctive pattern. While of the liquid type, the bowl is semi-spherical in shape, about 7½ inches in diameter, is replete with efficient expansion chamber, and is gimballed on an aluminium bracket with roller bearings. The bracket

is provided with the requisite magnet carrier and cover for correcting magnets. The card, in this instance, is horizontal, measuring 5 inches in diameter, marked and painted upon a light float, while it is read through a large adjustable prism. Care has to be exercised when mounting these compasses in position, since it is necessary to preserve the instrument from shocks and jars as far as practicable; this is done by means of shock-absorbing springs.

It being necessary for the pilot to be kept informed of the altitude at which he is flying, an instrument for this purpose is provided. This is the altimeter or height recorder, the calibration of the dial reading from 1 to 20 or more, each division corresponding with a difference of 1,000 feet. The aneroid barometer is utilised for this purpose, but is specially compensated for temperature. This latter provision is of vital import to the aviator, otherwise a false impression of height would be conveyed, the factor of correction varying according to the temperature, which exercises an influence upon the density of the atmosphere. Thus, whereas an aneroid reading of a climb through 1,000 feet, when the air has an average temperature of 50 degrees Fahrenheit, will be equal to an actual 1,000 feet, a similar reading with the air at 10 degrees Fahrenheit will only be equal to 922 feet actual distance. Similarly, if the atmosphere should be 70 degrees Fahrenheit while the ordinary aneroid will show 1,000 feet, the distance climbed vertically will be 1,040 feet. Hence the necessity for correction, and, as a rule, the altimeter is compensated for temperature to read up to 30,000 feet.

The time, of course, is given by the clock or watch. Here again, notably upon long distances, corrections are requisite. Thus, for instance, to an aeroplane going westwards over the

ACROSS THE ANDES BY AEROPLANE

On April 4th, 1919, Lieut. Cortinez in a "Bristol" monoplane flew from Santiago, Chile, to Mendoza, Argentina, and back. In crossing the Cordilleras the daring aviator was forced to a height of 20,000 feet. The above photograph shows the approach to the main range, the monoplane being at an altitude of 13,000 feet above sea level.

Atlantic, the day exceeds 24 hours in length, because the machine is overhauling or travelling in the same direction as the sun. New York time is 5 hours behind Greenwich. Thus, if we have an aeroplane travelling at 120 miles an hour, as did the "Vimy" trans-Atlantic machine, the 3,000 air miles between Greenwich and New York, while occupying actually 25 hours' steady flight, would be covered in less than a "day" by the clock, because the "day," to the aviator, would be 29 hours in length. In other words, if he left London at midnight on Monday, he would not arrive an hour after midnight on Tuesday at New York according to local, i.e. New York time, but as the clocks were striking nine in the American city. On the other hand, flying at the same speed in the eastward direction, he would have the sun against him, and so the day to the pilot would be 19 hours in length. In this instance, if he left New York at midnight on the Wednesday he would not reach London one hour after midnight on the Thursday, that is, 1 A.M. Friday, according to the clocks set by Greenwich, but as the clocks were striking the hour of six. For long distance travel, the aeroplane must be fitted with a timepiece as accurate as that carried by the steamship, for the simple reason that, should thick and heavy weather prevail during the journey, precluding the opportunity to take a position from the sun, the pilot would have to rely upon dead reckoning. He would calculate his position from the revolutions made by his engines, and from the knowledge of the number of revolutions necessary to drive him forward one mile. From the time he had been travelling at that speed, he would be able to estimate roughly his position.

Then there is the air-speed indicator. This instrument communicates to the pilot the actual or *independent* speed of

the machine; tells him the rate of progress through the air. I have emphasised the necessity to grasp this factor of speed in its relation to aerial travelling in another chapter. This instrument is highly ingenious, but it does not allow for altitude. That is to say, while correct near the ground, it does not read off directly on to the dial the actual travelling air-speed at a given height. The calculation necessary to adjust the error, however, is very simple, it only being necessary to multiply the speed as indicated upon the indicator by the number of thousands of feet shown on the altimeter, and to divide the sum by 60, adding the answer to the speed-meter reading. Thus, supposing the speed indicator registers 120 miles per hour and the altimeter 10,000 feet. We multiply 120 by 10—10 indicates that number of thousands of feet—which equals 1,200, and which divided by 60 gives 20. This is added to the air-speed indicator reading 120, making 140 miles per hour, which is the true air-speed at the height of 10,000 feet.

Another important instrument is the inclinometer. This is somewhat similar to a spirit level, and is really designed for a similar function—namely, the inclination of the aeroplane to the right or to the left. It comprises a slightly curved tube of glass, which is placed in a convex position upon the dashboard, preferably in the centre, though it is sometimes placed to one side. The tube is mounted in a graduated case, the centre of which is marked zero. If the bubble in the tube rests over this zero mark, then the machine is level in the lateral plane when travelling a straight course. But if it should be tilted to one side or the other, the bubble naturally moves, and as the scale is graduated in degrees to the right or left of the zero mark up to 20 degrees, the pilot can read off the actual inclination of his machine, in degrees

from the horizontal, from the position of the bubble in its relation to the scale. If the bubble is over the 4 degrees mark to the right of zero, then that shows the machine is inclined by 4 degrees in the opposite direction—that is, to the left, and *vice versa*. This instrument can also be utilised as a side-slip indicator when making a turn. Although to make the turn the machine must be banked or inclined, the bubble, provided the angle is correct, will remain at zero by virtue of the centrifugal force. Should it move upwards, it shows instantly that the machine is slipping bodily down the bank or angle described.

Other recording instruments comprise the tachometer, or indicator, showing the number of revolutions the engine is making per minute, read off in hundreds, thereby enabling the pilot to satisfy himself that the engine is developing the requisite power to enable a specific evolution to be carried out, that she is standing up to her work, and to guide him in keeping her up to her normal full speed or to squeeze out that little bit extra which he may require and which he can secure within limits. Another instrument enables him to maintain an even keel fore and aft. Then a gauge shows the pressure of the oil lubricating system, while a similar instrument keeps him posted up with information concerning his petrol supply by recording the pressure maintained upon the feed system to the engine.

Another important instrument indispensable to the pilot is the thermometer, giving a constant reading of the temperature of the water in the cylinder jackets and the radiator. As I have pointed out on another page, the density of the atmosphere exercises a far-reaching influence upon the power developed by the engine. It has a similar effect upon the water in the cooling circulation. As is well known, at sea

level, the pressure of the atmosphere, when the thermometer registers 32 degrees Fahrenheit, or the barometer stands at 30 inches, is 14·7 lb. per square inch. As we rise into the air the pressure falls, and with it the temperature. Thus, when the aeronauts, Süring and Berson, ascended in their spherical balloon on July 31, 1901, to attain an altitude of 34,000 feet—approximately 6¾ miles—they found that the temperature of the air fell at the rate of 2½ degrees per 1,000 feet from what it was on the ground up to 4,000 feet; 3 degrees Fahrenheit per 1,000 feet from 4,000 to 17,000 feet; and 4 degrees Fahrenheit per 1,000 feet between 17,000 and 28,000 feet. Consequently, while the thermometer registered 50 degrees Fahrenheit on the ground, at the altitude of 28,000 feet it stood at −44 degrees Fahrenheit, which represents a total difference of 94 degrees.

Moreover, as we rise, owing to the air becoming rarer, the boiling point of water is lowered. Whereas the kettle on the hob in our home boils when the temperature of the water has been lifted to 212 degrees Fahrenheit, at an altitude of 10,000 feet it will boil at 194 degrees. From this it will be seen that the radiator is necessarily exposed to considerable and violent extremes of temperature, and that arrangements must be introduced to shield it in the low temperatures experienced in the higher atmosphere, otherwise efficiency is certain to fall off. This is accomplished by means of shutters or blinds, controlled by a lever from the pilot's seat, and which can be set at any desired point between the fully-opened and closed positions, the pilot being guided in the setting of his shutters by the reading of his thermometers and his travelling intentions.

Numerous other instruments have been designed to assist the pilot in his work, such as the drift indicator for calcu-

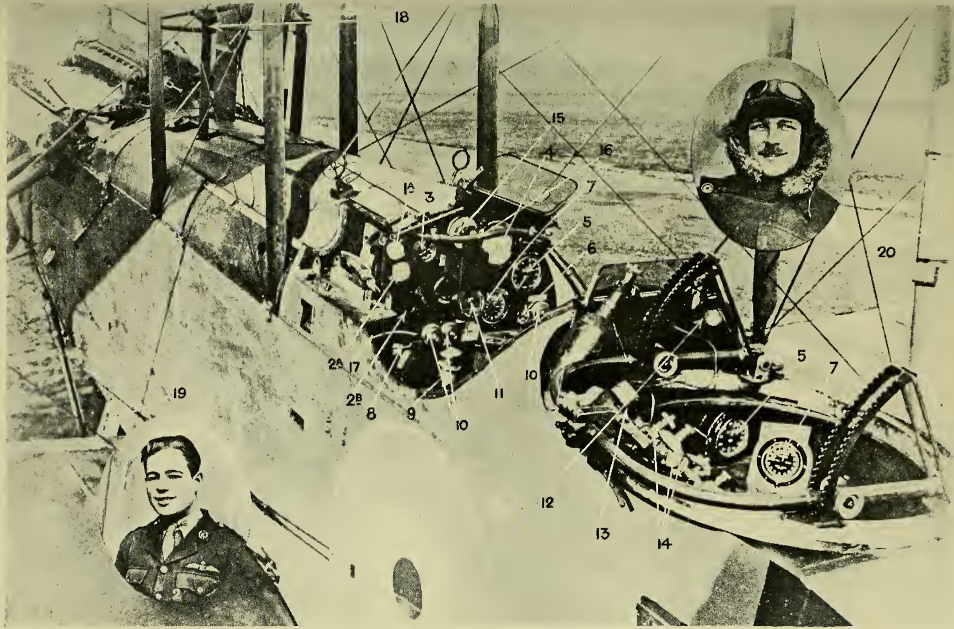
lating wind drift and ground speed. Obviously, if the aeroplane be travelling across the wind, and the latter is blowing at an appreciable, or even low, velocity, it is bound to force the plane out of its course, in the self-same way as a cross-current will deviate a steamship from its course. If one be flying over land, it is a relatively simple matter to calculate the amount of drift and to adjust accordingly; but when flying over the open sea, with the heavens obscured and no marks capable of being used as bearings, the aviator must rely upon his own judgment to a very pronounced degree, and maintain his course by dead reckoning. The drift indicator has not yet been brought to a state of all-round dependability. Another instrument, which has been contrived to co-operate with the drift indicator is the wind calculator; but the manipulation of this instrument depends upon observations carried out with the drift indicator. The air sextant is a further ingenious instrument for taking altitudes from an aeroplane by means of a prism attached to a centre plate or worm wheel, which is rotated by means of a worm having a micrometer head. The back and front horizons are reflected into the same field as the celestial object observed, and in this way a very rapid and accurate observation can be made.

Every instrument placed upon the dashboard is fitted with a small and brilliant electric torch set in a swivel mounting, and each is lighted independently by a push-button switch, similar to that employed in connection with an electric bell system. The small, compact board carrying these switches is placed at a point convenient to the aviator, enabling any one to be pressed with the utmost facility. Furthermore, the more essential instruments have the degrees of their graduated scales or other markings painted with radium luminous

compound, enabling them to be read in the dark without switching on the electric light.

Nowadays the wireless installation constitutes one of the most vital nerve centres of the flying machine. This not only enables the pilot to keep in touch with the land below, or passing vessels, but is also of far-reaching importance in guiding him upon his course. What is known as uni-directional wireless has been brought to a high degree of perfection. Wonderful progress has been recorded in connection with wireless telephony. In many quarters it is believed that talking through space will supersede telegraphy.

The bridge of the airship is similar to that of the aeroplane, although many additional instruments have been devised to assist the navigator and commander. The balloons are controlled from this point through the manœuvring valves, which are operated by hand to vary the trim of the vessel, and by their operation a certain quantity of hydrogen is permitted to escape. Then there are the water ballast bags to be taken into consideration, as well as many other incidentals, the navigation of a dirigible being somewhat more complex than that of the heavier-than-air machine. But in both instances the manifestation of ingenuity is pursued merely to provide mechanical aids to the man at the wheel to facilitate finding the way through the air, and contributing to the safety of both the machine and its passengers. Perfection in this direction has not yet been wholly attained, but the hazard of aerial travel to-day is virtually eliminated. Dependence upon the human element has not been wholly overcome; the aerial counterpart of the dead man's handle, incidental to the electric train, has not yet been evolved for the flying machine; but the trend of inventive brilliancy is toward that end. When this



HOW THE "NAPIER" ALTITUDE RECORD OF 30,500 FEET WAS MADE

1. Capt. Andrew Lang, R.A.F. (Pilot). 2. Lieut. Blowes, R.A.F. (Observer). 1A. Stop Watch. 2A. Petrol Pressure Gauge. 2B. Water Temperature Thermometer. 3. Oil Pressure Gauge. 4. Air Speed Indicator. 5. Engine Revolution Counter. 6. Oil Temperature Thermometer. 7. Height Recorder. 8. Air Control (Carburettor). 9. Statiscope for Angle of Flight. 10. Engine Switches. 11. Compass. 12. Oxygen Bottles (Observer's Cockpit). 13. Oxygen Pressure Gauge (Observer's Cockpit). 14. Oxygen Control Valves (Observer's Cockpit). 15. Petrol Cock. 16. Petrol Pipe to allow for fitting of petrol consumption gauge. 17. Inclinometer. 18. Air-Driven Petrol Pumps. 19. Corner of Radiator. 20. Atmospheric Thermometer.

is perfected, the way of the air should be as safe as that of the road, rail, or sea. Should anything go wrong in the air to the propelling unit or to the man at the wheel, there is no reason why the earth should not be reached in safety by converting the machine from a live and throbbing entity to an inert glider, following an easy and safe angle to the ground.

CHAPTER XII

The Rules of the Road in the Air

WITH the world-wide opening of the Highways of the Air, the introduction of more or less defined services, inauguration of trunk routes, experimental voyages, and joy-riding in general, the necessity for the elaboration of rules and regulations concerning the control of such traffic becomes obvious, not only in the interests of those using the air, saving them from accident and possible disaster, but of those upon the earth beneath. We have the golden rule of the road observed in our streets whereby the users of vehicles know:

> *If they keep to the left they will be right:*
> *If they keep to the right they will be wrong,*

and also that of the sea, especially at night, whereby the navigator, in passing, knows that:

> *Green to Green—Red to Red—*
> *Perfect safety—Go ahead,*

the observance of which conduce to the safety and well-being of all, as well as the smooth, regular working of all traffic.

So far as the air is concerned, the elaboration of rules of the road is somewhat more complicated, for the simple reason that the flying-machine has movement in the three dimensions. An aeroplane or airship can not only pass to the right or to the left, but also above or below. Moreover,

although much planning of trunk routes has been discussed, very little definite plotting has been carried into actual operation. We have not yet reached the stage when the aerial lanes are as sharply defined as those which have been plotted over the seven seas. Nor, as yet, have we any competent authority comparable with the Board of Trade, either engaged in the framing of these regulations, or invested with full authority to enforce them and to see that they are truly honoured. Hitherto the Royal Aero Club has been responsible for a certain domestic code, prepared before the war, but which has achieved little since 1914, owing to the uncertainty of its position and the general tendency to disapprove of any private organisation being vested with powers which ought to belong to an official department. Then there is the Fédération Aeronautique Internationale seeking to control the issue in the international or universal sense, which is similarly opposed in many directions. The true department which should assume this responsibility is the Air Ministry, and, no doubt, it is the intention of this official department to become the supreme authority in all matters associated with movement in the air, from the issuance of pilots' licences, authority to use machines, airworthiness, to the framing and co-ordination of the rules of the road, investigation of accidents, apportionment of blame in the cases of disaster and mishap, and general organisation of constitutional aerial laws.

By virtue of the fact that we possess and maintain the largest fleets of aeroplanes and airships, and are already blazing the trails through the air to various corners of the earth, we should elaborate a complete code of rules to meet every possible contingency and to cover every conceivable circumstance. It is a task which requires to be carried out with extreme care and prolonged deliberation. Then, should

the stern test of practical application establish their value, we may safely anticipate that our lead will be followed by other countries, possibly without any modification or only such slight amendments as to adapt them to local conditions. We followed this policy in regard to the railway and the steamship, and in both instances the rest of the world followed, either accepting our ideas *in toto,* or as a model for their own systems, revised to meet the requirements of their own legal and traffic situation.

From whatever point the issue be viewed, it is apparent that the rules of the air, in the long run, must be framed to meet local and international requirements respectively. The two situations are so vastly dissimilar. The former concerns the control of traffic over a single country; the latter involves the crossing of the territory of another power. For many years it has been a matter for dispute as to whether a nation or an individual was entitled to the air above its, or his, territory or property. The legal and political aspects are thus indissolubly associated with this momentous question. It does not arise in connection with the ocean because the powers have collectively recognised the territorial waters limit, and that all water beyond that invisible fence is available to one and all without let or hindrance. But with the air it is different. The gravitational law upsets any determination of territorial air limit. No matter at what height an accident may happen, involving the destruction of the machine, those on the earth below are certain to experience the effect of the falling pieces, while it might so happen that one piece would fall on one and another tangible fragment on the other side of an international boundary. Accordingly, it has been decided that the air above a country belongs to that country without any altitude reservation whatever.

The Rules of the Road in the Air

Previous to the outbreak of war, practically only one rule of the air was elaborated, and this was observed, more or less, during the period of hostilities. This was of a very broad character, and was dictated more by instinct than deliberate determination. It concerns overtaking machines in the broad aerial ocean. The rule is to keep to the right when meeting machines proceeding in the opposite direction, and to steer clear when overtaking, or, if meeting at an angle, the machine on the right of the other must hold to its course, the second pilot steering clear. It is a somewhat vague rule, but it has proved successful, and now, as the result of custom, is generally upheld. But it only applies, or, at least, is observed, in the open air. In the vicinity of aerodromes, where the air was relatively thick with aeroplanes during the period of intensive training for war service, other "local" rules were laid down for the guidance of the "quirks" or learners. There was no attempt to elaborate general rules for widespread application; they were adapted to the exigencies of the individual training school.

On May 1, 1919, civilian flying was officially inaugurated by the withdrawal of the Defence of the Realm regulations, which had been in existence for five years. However, as previous to the outbreak of hostilities general flying was unknown, the foregoing date may be accepted as Emancipation Day in its application to the air. Coincident with the official recognition of civilian flying, a code of rules known as "Aerial Navigation Regulations, 1919," was officially issued by the Controller-General of Civilian Flying attached to the Air Ministry, which has led to the general assumption that this department is destined to become the sole controlling authority over all movement in the air. The code in question is certainly comprehensive so far as it goes, and the regu-

lations involved have been drawn up in the interests of the aviators, members of the general public, as well as of designers and builders of machines. The regulations in question apply only to the United Kingdom, and, at the time they were issued, did not permit general flying to places abroad, the laws concerning this side of the question being an issue for International determination and settlement. They are confined to civilian flying; they do not affect military or naval aviation in any respect.

The rules in question are somewhat stringent, as they should be if the development of flight is to be continued to a logical commercial conclusion. All machines must be registered, and must carry the prescribed registration and nationality marks of identification. The aviators and others engaged in the management of the machines must be licensed, while pilots, navigators, and mechanics are compelled to submit to a medical examination, to produce certificates of competency, and, if required, to undergo practical tests. The necessity for such precautions is obvious. During the war hundreds of pilots were trained and obtained their wings. Many, after a period of service, were retired as "permanently unfit for pilot or observer," and the above regulation is to prevent such pilots from securing control of a machine in service. To allow them to do so would be to invite disaster, and so far as the air is concerned would be detrimental to every interest.

The protection of the public against the machine is as complete as that against an incompetent or unfit pilot. No machine is permitted to engage in passenger-carrying service until it has been examined to determine its airworthiness. As is the case with vessels of the mercantile marine, periodical overhaul and refitting are demanded, while an examination

must also be conducted before each flight. The certificate of airworthiness, together with other desired details, must always be carried in the machine in question. By this action the public is protected against possible conveyance in a dangerous craft. A second-hand aeroplane is not like a second-hand motor-car or cycle. Should the latter break down during a journey, from failure of any part, little or no damage is inflicted; but to allow a dubious, unsound aeroplane or airship to proceed into the air would be disastrous. This is not to say that a second-hand aircraft cannot be converted into a sound machine; but the process of stripping, overhaul, and replacement of defective parts is likely to be a costly process, and the official determination to guard against lack of airworthiness, in the same way as the Board of Trade exercises its control in connection with the seaworthiness of a vessel, is likely to act as an effective deterrent to enterprising speculators bent upon the introduction of joy-rides at popular resorts. Patchwork overhaul of a purchased machine in the attempt to obtain airworthiness is also effectively countered, because the Ministry possesses the power to cancel or suspend any certificate of airworthiness which may have been issued in the event of doubt arising as to the airworthiness of the machine, or of the safety of the type to which it belongs.

Moreover, to induce those engaged in the conveyance of passengers by air to keep their machines in the pink of condition, otherwise perfect airworthiness, no machine must ascend with passengers unless it has previously been thoroughly inspected upon the day of the flight, and this inspection must be carried out by a duly authorised inspector. The pilot is not entrusted with the responsibility for determining this question. This preflight inspection is additional

to the periodical general inspection. In this manner the pilot is protected because he is relieved of determining the soundness of the craft placed in his hands. Furthermore, a machine is only registered to carry a certain number of passengers, and none in excess of this number may be carried in any circumstances, thus avoiding overloading, or applying to the aeroplane and airship the "Plimsoll" mark incidental to sea vessels. As a final protection, the machine must carry a log-book, which must be kept up-to-date, thus applying another practice of the sea to the air. This condition is applicable to machines engaged in the movement of freight as well as those concerned with the transport of passengers. From the foregoing it will be seen that the practice identified with the sea has been extended, so far as conditions will allow, to the air, and should be adequate as far as human effort can possibly contrive to secure the fundamental element, "safety first."

As may be imagined, no mails may be carried viâ the air without the sanction of the postal authorities. Nor may wireless be installed and used without the consent of the Postmaster General. This may appear at first sight to represent a distinct brake upon the development of etheric communication, but it merely brings the aeroplane into line with the regulations concerning the use of wireless upon the land. At the same time there is no intention to arrest inventive progress. Application to the authorities is certain to meet with sympathetic interest, and, if the conditions so warrant, the requisite licence will be extended. But even then it will be governed by the conditions concerning wireless operations which have been elaborated by the Air Ministry, which again is a useful precaution, inasmuch as the utilisation of wireless in the air, unless certain requirements are fulfilled, is likely to prove dangerous to those in the

machine, more especially if the latter be of the lighter-than-air class.

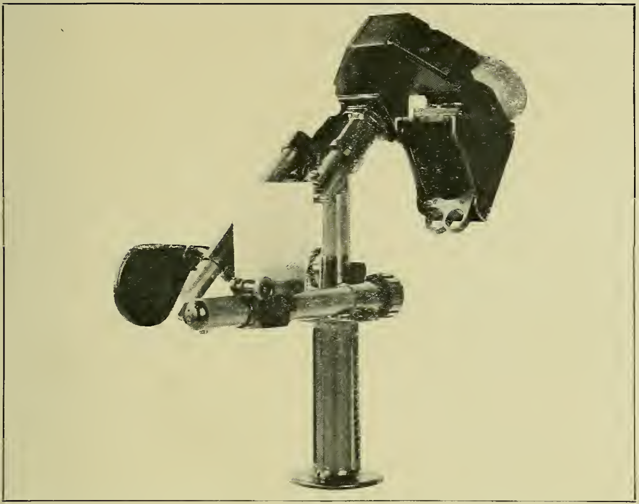
The rules laid down to ensure the general public safety are of a most rigorous description. Flying over towns and cities is forbidden, except at such an altitude as will enable the pilot to glide to make a safe landing outside the town or city in the event of his engine "conking"—that is, failing—or from any mechanical breakdown. Nor must any article be intentionally dropped from the machine while in flight. The smallest object discarded from an altitude is likely to cause grievous damage or injury. A penknife may weigh less than half an ounce, but if allowed to fall from an aeroplane travelling at an altitude of 1,000 feet will acquire sufficient impetus during its descent, occupying less than 8 seconds, to strike the ground with a terrific blow. So far as the lighter-than-air craft are concerned, the ballast which they are at liberty to discard is sharply defined. It must not be other than fine sand or water.

During the war, as a result of the rigid training imposed, our airmen became expert and resourceful in the performance of exciting manœuvres, such as looping the loop, spiralling, and other feats of "aerobatics," as these evolutions are colloquially called. But, however essential they may have been to wage war against a cunning enemy, they are useless to civilian flying, except in the nature of sideshows. Doubtless the military aviator who has acquired a remarkable proficiency in stunting will regret official interference with his daring and ability to demonstrate control of the machine in an exhilarating manner; but the regulations upon this phase of the subject are very stringent. Trick and exhibition flying over any city, town, or village is strictly prohibited. An aviator must not even give expression to his supremacy in aerobatics

at regattas, race meetings, or exhibitions unless express permission for such feats has been extended. Neither must he fly at such a low altitude as might be construed into a menace to the public on the ground below, or to buildings.

Infraction of any of the regulations which have been laid down is likely to be visited with exemplary punishment, unless the offending pilot can establish conclusive proof that contravention of the rules was unavoidable, such as unexpected failure of mechanism or stress of weather. The delinquent is exposed to the penalty of six months' imprisonment or a fine of £200. If the offence be glaringly flagrant, and no extenuation be forthcoming to justify his offence, he is likely to have both penalties visited upon him.

Public opinion is disposed to endórse the rigidity of the rules and regulations which have been framed. At first sight their severity may prompt the feeling that they are likely to handicap progress. But this is not so. Every encouragement must be extended, as is being done, to develop and popularise the way of the air. This is evidenced by permission to conduct joy-ride flights, which are achieving a useful purpose in educating the general public to the complete safety of the new highway for locomotion. But unless some form of authority were exercised, the frequency of accidents due to the employment of unsafe machines handled by pilots lacking proficiency, skill, nerve, or the essential flying temperament, would inflame public opposition, and tend to put back the clock very pronouncedly. There was antagonism to the railway, the steamship, and the motor car, which throttled development for a long time, and which led to harassing legislation. If the development of aerial locomotion can be absolved from such an outbreak of antipathy it must advance in popular favour at a rapid rate.



INGENIOUS INSTRUMENT FOR CALCULATING EARTH DISTANCE

Photo. by courtesy of Messrs Henry Hughes & Son, Limited.

Women making the airman's sextant for taking altitudes from an aeroplane.

FINDING THE WAY THROUGH THE AIR

In so far as the task of evolution is concerned, control is made as slightly irksome as the circumstances permit. A new type of aeroplane will be subjected to inspection and examination, as well as test, to determine its airworthiness. Satisfactory emergence from the ordeal will result in a licence being granted, and all further aircraft of that type will need only to be subjected to inspection by a competent member of the builder's staff, arrangements to which end can readily be made. At the same time, however, the Air Ministry holds an independent attitude, and is free to inspect further craft of the one type. Should this examination establish the lack of airworthiness of the craft, all further construction of the type in question must cease because the possibility of obtaining further licences or certificates is destroyed. If a manufacturer or designer desire to obtain recognition of a new type, he must secure the admission of the Air Ministry in regard to its safety; workmanship and materials employed must obtain the approbation of the department; while, finally, the builders must demonstrate the safety of the machine by means of flying trials.

In so far as the actual rules of the road are concerned, these are not of an elaborate or bewildering character. Every effort appears to have been made to render them as simple as possible. However, they serve to cover the various situations likely to arise effectively, and should lead to the disappearance of collisions in the air such as have been recorded, and in the event of such an accident occurring, should appreciably facilitate the apportionment of the blame.

From the nature of the rules which have been laid down it is evident that the aeroplane has been recognised as the machine possessed of the highest manœuvring capacity, and that its inherent speed is a factor conducing to quick evolution

while aloft. In this respect it is placed upon the comparative level of the greyhound of the ocean, the airship being regarded as the aerial counterpart of the sailing ship. Aeroplanes must always give way to lighter-than-air craft, whether they be free balloons or airships. On the other hand, airships, from being provided with the capacity to secure an independent speed, are called upon to give way, in every instance, to the balloon, whether the latter be free or captive. Apart from this rule aeroplanes and dirigibles are placed upon an equal level.

When a flying machine, aeroplane or dirigible, is overtaking another motor-driven aircraft, whether it be heavier or lighter than air, care must be taken by the following vessel to ensure that it is not likely, by holding on to its course, to pass the other within a distance of 200 yards of any part of the leading craft. The latter should keep to its course, the pursuing ship altering its helm and changing its own course so as to pass the other beyond the prescribed limit of distance. If two flying machines are approaching one another from opposite directions, head on or nearly head on, both are called upon to alter their respective courses to starboard. In those cases where two vessels are approaching one another along courses which must intersect, that vessel which has the other on its starboard must keep out of the way.

Ability to move freely in the vertical plane is realised as likely to lead to accident unless the contingent be duly safeguarded. For instance, the pilot of a fast-moving aeroplane, overtaking an airship upon an identical course, naturally wishes to hold to his own course, and might be disposed, in the desire to maintain his course to dive under the dirigible. This method of passing is rigidly forbidden, it being expressly laid down that the overtaking machine must alter its

course, so as to pass the other at the prescribed distance in the horizontal plane, and must not pass the vessel ahead by diving under it.

It is also recognised that as the aerial routes become established, vessels will be disposed to keep to that route in exactly the same way as ocean liners, although the sea is wide, hold on as much as practicable to the defined steamship lanes. Accordingly, all aircraft following an officially recognised air route, when it is safe and practicable, must keep to the right-hand side of the air-lane.

Landing grounds, whether they be on *terra firma* or water, are likely to become congested areas. But such stations, of course, will be under distinct control, and ultimately, no doubt, will be governed by distinctive rules and regulations affecting both short-distance and long-distance craft. Hard and fast rules are somewhat difficult to lay down, because both the aeroplane and the airship must land and "take off"—that is, ascend—head to the wind, which is not a constant factor, and even may vary in direction at ground level from that prevailing aloft. The landing vessel is extended premier recognition, it being incumbent upon the vessel about to "take off" to make sure that it can do so without risk of collision with an alighting craft.

Under conditions of clouds, fog, mist, or general low visibility, it is difficult to lay down any hard and fast rules for observance. All that can be done in this direction is to impress upon the aviators the necessity to keep a sharp look-out, and to proceed with caution, the existing circumstances and conditions being taken into full consideration.

While observance of the foregoing rules of the road will undoubtedly facilitate movement in the air with complete safety, and will minimise the responsibility of the aviator as

of the mariner upon the sea, blind adherence is not going to represent complete absolution from blame in all cases of accident. In the air, as in other fields of transport, certain obligations are imposed upon the man in charge of the machine. He must keep a sharp look-out, must attend to the lights upon his own machine, take due notice of any signals that may be given, and, when placed in a tight corner, must give full rein to the promptings of his own common sense. Initiative in this, as in all other fields, often proves the only way out of a critical situation, since circumstances will develop against which it is absolutely impossible to prescribe an inflexible rule.

Perfection of safety in fast railway travelling has been mainly due to full digestion of the lessons taught by accident. The pre-eminence achieved by the British railways in this respect has been built upon disaster. It has led to the introduction of numerous expedients to minimise accident, and to reduce dependence upon the human factor, which is always likely to err or fail at a supreme moment, to an increasing degree. It led to the introduction of the block-signal system, the perfection of the automatic air and vacuum brakes, and other safety devices too numerous to particularise, as well as to improvement in the technical details of the locomotives, rolling-stock, and permanent way, and methods of controlling and manipulating traffic. A similar story may be related of the sea. And as with the railways and the ocean, so it will be with the air. During the war accidents and mishaps to machines did not receive the investigation they demanded; the majority were due to excessive zeal upon the part of the pilots, or the unavoidable submission of the machine to some stress for which it was never designed. Under peace conditions all is changed. Every accident is to be officially and

technically investigated along the broad lines followed by the Board of Trade in regard to the railways and steamships. Inquiries are to be held to discover why a machine crashed, with a view to avoiding a repetition of the disaster. Accordingly, crashed machines must not be moved until they have been examined by the technicians exactly as, and where, they fell. The observance of this requirement will promptly lead to the elimination of faulty machines and types, if such are at present being flown, and should contribute materially to our knowledge of the laws concerning dynamic flight, of materials, aeromotors, and of the action of the air itself, as well as stimulate inventive effort in the evolution of safety devices of true significance.

Of course, with the presentation of facilities to wander hither and thither over the face of the earth, according to desires or the calls of commerce, further laws will be elaborated. These, for the most part, however, will be found to be concerned with matters of fiscal import to meet the desires of the customs and excise departments concerned. They should not affect the broad principles governing the safe movement of passengers, freight, and mails through the air, any more than individual nationality affects the working of steamships upon the open seas.

CHAPTER XIII

The Highways of the Air

WITH the acceptance of the air as a field for commercial locomotion, it was only logical to expect the definition of "lanes" corresponding with those criss-crossing the seas for the conduct of communication. The air may be broad and deep, but commerce is so exacting as to demand that the connection between the points involved shall be one as closely coinciding with Euclid's definition of a straight line, or, at least, as strictly in accordance with the bird's flight as circumstances will permit. The trend of this development was distinctly indicated upon the inauguration of civilian flying on May 1, 1919, by the authorities establishing seven trunk routes between London and various parts of the British Islands, and the Continent.

Although, as stated, the air is broad and deep, haphazard wandering through this vast ocean would be beset with dangers innumerable. The flying machine is invested only with a specific radius of action, or mileage, upon a single fuel charge, this endurance naturally varying according to the type of the machine. But, while many of the craft in question would undoubtedly be able to span the distances involved in non-stop flights, it must not be forgotten that the unexpected must receive due consideration. And one must not forget that dominant force—the weather. Accordingly, it is obviously expedient that points should be established to allow craft of

the air to secure refuge in times of adversity, as when beaten by the weather, to obtain replenishment of fuel tanks, and, if the occasion so demands, to receive mechanical attention. Such stations, however, could not be dotted promiscuously about the country, for the simple reason that an aerodrome, from its expensive nature and somewhat elaborate equipment, is a somewhat costly undertaking to establish and to maintain. Of course, although these trunk lines have been laid down, it is not to say that they must be rigidly kept by the flying machines, since one might take to the air off the main road. Nevertheless, it is anticipated that those using the air for movement will make straight for the defined highway, entering the nearest lane at the most convenient point, so as to be able to take advantage of the facilities offered *en route* if desired.

This opening of the trunk routes is frankly of a provisional nature, inasmuch as experience is necessary to ascertain whether they coincide with those demanded by commerce; at the same time it has created a number of what may be termed air-ports. The hub of this net-work is London, the terminal aerodrome for which centre is Hounslow, the other ports of importance being Belfast, Bristol, Dublin, Manchester, Plymouth, and Renfrew. With the exception of Manchester, these are terminals, the Lancashire city being on the run from the metropolis to Belfast. In addition to the foregoing, which concern the British Isles wholly and solely, routes have been defined between Holland, Scandinavia, and the Continent in general, the compulsory landing points in connection with which, to meet the requirements of the Excise and Customs as well as immigration authorities, being respectively Hadleigh in Suffolk, New Holland, Lincolnshire, and Lympne in Kent. These are not

essentially terminals, but serve rather as clearing stations, where Customs facilities, especially in connection with aerial transit, have been provided, the flying machines subsequently proceeding to or from Hounslow. The routes which have been defined are as follow:

LONDON (Hounslow) to

BELFAST.	BRISTOL.	DUBLIN.	SCOTLAND. *Via*	PLYMOUTH.	THE CONTINENT.
Hucknall Sheffield Manywell Heights *Didsbury Scale Hall Luce Bay Aldergrove	Filton	Witney Castle Bromwich North Shotwick	Wyton Harlaxton S. Carlton New Holland Doncaster Copmanthorpe Catterick Redcar Newcastle Turnhouse Renfrew	Eastleigh Cattewater	HOLLAND—Hadleigh (*route via Harwich*) NORWAY AND SWEDEN—New Holland (*route via the Humber*) Other parts—Lympne.

These routes became immediately possible owing to the number of aerodromes which were available, as a result of the operations carried out by the Government to meet the requirements of the war. When the Armistice was signed on November 11, 1918, there were 337 aerodromes and landing stations scattered throughout England, Scotland, Ireland, and Wales. It was found possible to relinquish 34 of this number immediately, to serve as intermediate stations upon the authorisation of the resumption of general flying. The proposal is to allocate 120 of these aerodromes in all to commercial operations, but it was found impracticable to release them all simultaneously from official service for the purposes of commerce. These stations are well equipped with exten-

* For Manchester.

sive buildings, providing docking, hangar and fuel supply facilities, as well as repair shops, tools, and mechanics.

In plotting out the first air lanes, the authorities did not aim at providing the shortest communication between the distant terminals, but endeavoured to serve as many important points *en route* as possible. Thus, it will be observed on the Scottish route, that the lane lies by way of Doncaster and Newcastle, that to Belfast touches Sheffield and Manchester, while the Plymouth line, by proceeding by way of Eastleigh, serves the Southampton area.

Probably the first flight to be made along any of these routes was that made by Mr. H. J. Thomas, a director of the British and Colonial Aeroplane Company, Limited, of Bristol. Having an important appointment with Major-General Seely at the Air Ministry in London, this gentleman took the opportunity, offered by the removal of all restrictions upon private flying on May 1, to make the journey through the air, the train service between Bristol and London, at that time, at all events, leaving much to be desired. A Bristol "coupé," described in another chapter, was selected for the run, and although the wind was boisterous, and rain was falling heavily, while the clouds were low and misty, rendering the general flying conditions most unfavourable, he set out with Lieutenant Uwins at the wheel. The strong wind being behind them, a fast flight was made, Swindon being crossed in 12½ minutes from the start, representing a run at 160 miles an hour, while Didcot was picked up in record time. Shortly afterwards the aeroplane dashed into a blinding rain-storm and a heavier wind. Thereupon the pilot decided to change his course in order to avoid the storm centre and to render travel more attractive to his passenger, bearing north-east-

wards until he reached Aylesbury, when he turned, to approach Hounslow from the north instead of from the west. Despite the circuitous route the landing was made at Hounslow a little before 11.30 a.m., the run from Bristol, about 100 miles as the crow flies, but considerably more by the route which was followed, having occupied 58 minutes 5 seconds. Mr. Thomas was the first civilian passenger to land at any officially appointed aerodrome in the country, although later that opening day another Bristol machine landed at Manchester after a flight from Reading, with a parcel of cinematograph films for display in the Lancashire city that evening. The flight made by Mr. Thomas was regarded as of striking significance in more senses than one. The era of commercial flying could scarcely have been ushered in under more adverse weather conditions, but the journey conclusively proved that a machine of scientific design and solid construction has very little to fear from weather when skilfully handled, while at the same time it emphasised the flexibility of the way of the air, enabling centres of meteorological disturbances to be circumvented.

But, generally speaking, it is conceded that the trunk airways of Britain will never be called upon to cope with heavy traffic, except upon distances from 300 miles upward. The time saved is not considered to be adequate to warrant the heavier expense of the journey. Of course, if the cost of aerial transportation can be brought to the level of first-class railway fares, it will have a much more attractive future, because full advantage will be taken of the opportunity of being able to start at any time convenient to the passenger, instead of being compelled to adhere to railway time-tables. It is the longer routes which are more likely to make appeal, especially those involving the negotiation of the Irish Sea,

as, for instance, between Dublin and Belfast and British centres, where the time occupied by the existing communicating facilities is a serious factor, not to mention the opportunity to avoid an uncomfortable sea-crossing.

British commercial flying by aeroplane will commence to develop once the Continental routes are opened. Then we may anticipate trunk airways between London and other provincial cities ramifying from London and the leading provincial centres to various parts of the Continent—Paris, Brussels, Antwerp, Rotterdam, and other cities within easy reach. The aeroplane is not likely to be called upon to make journeys exceeding five or six hours in duration until it has undergone considerable development. Its present limited dimensions and degree of comfort are distinctly adverse. The above-mentioned cities can be reached from London within 2½ to 4 hours, which probably will be found to represent the approximate limit of endurance upon the part of the passengers. Inability, or only restricted opportunity, to stretch the limbs will act as a deterrent, to all but the most persistent and to those who are prepared to tolerate discomfort and inconvenience so long as they can reach their destination within less time than is possible by any alternative means of communication.

It is quite possible, moreover, that the Continental airways will follow the circular route system, as, for instance, London—Paris—Brussels—Antwerp—Rotterdam—Harwich—London. Such would offer the advantage of the short-stage journey, with the majority of the passengers making the flight from stage to stage at one time. That is to say, at Paris the passengers from London would disembark, and the machine be filled with others wishing to proceed to Brussels. At the Belgian capital another complete change over would

take place, those embarking being destined for Antwerp, and so on round the circuit.

Of course, as aerial travel develops, linking-up services will be created, radiating from each of the above-mentioned points. Thus, from Paris another circle might be described of about 250 miles radius to embrace Lyons — Berne — Cologne, or a stage-route, Paris—Orleans—Tours—Bordeaux — Toulouse — Marseilles — Lyons — Berne — Dijon — Paris. From the commercially strategical points on this stage other similar circular routes could be advanced, as, for instance, Lyons—Marseilles — Nice — Genoa — Florence — Bologna—Venice—Milan—Turin—Lyons. In this manner it would be possible to cover Europe by a series of overlapping zones or circles, with the points of intersection forming possible junctions affording facilities for changing over from one route to the other. But, in every instance, attempts would be made to reduce each stage of the journey to the limit appealing to the passenger who does not appreciate being cribbed, cabined, and confined for more than two or three hours on end.

Moreover, one has to take into consideration the physical endurance of the pilot. Flying is monotonous, as every airman will admit, and it is certain to become pronouncedly so under civilian conditions. Swinging along in a straight line, at a constant speed, keeping a level keel, describing such turns as are necessary in circles of large radius, and keeping approximately to a constant altitude, is probably the most monotonous tax upon driving ability that one can conceive, especially after the route has been covered so many times as to rob it of all novelty. The pilot will probably become as "fed-up" with his journey as the passengers. To permit such a feeling would be fatal, as it would lead to inadvertent care-

lessness. It must not be forgotten that, under service conditions, the flying man was able to break the monotony of the flight. He could soar to the extreme altitudes, carrying his climb to the limits of his machine, and indulge in aerobatics—zooming, looping the loop, spiralling, gliding, nose-diving, and what not—to vary the tedium of his stay in the air—all of which variations to eternally steady ploughing uneventfully forward are denied him under civilian conditions upon a sedate passenger and freight-carrying service. It is impossible to advance the work of the engine-driver upon the footplate, or the captain upon the bridge of an ocean liner, as a parallel. There is no other system of locomotion comparable except, perhaps, it be the submarine, and that, as we have been freely told, is as monotonous as movement by the air.

Of course, remarkable non-stop flights are advanced as instances of rapid travel, but they cannot be expected to be brought into daily or regular service. There is a spice of adventure about such feats which is lost in a regular service. They do not constitute such tributes to the machine as to the endurance of the men at the wheel. In the air, as in the factory, and all other fields where machinery is employed, the continuous running of the mechanism without a stop is dependent upon the staying power of the man. And the machine will always beat the man. For this reason alone, therefore, we must regard the aeroplane in its present form as a vehicle of the hop-skip-and-a-jump order, flying from point to point, the distance between which will be relatively brief, and will not be found to exceed four to five hours' duration.

The aeroplane, however, is an ideal vehicle for this short-distance traffic. It is the business which will prove the most

lucrative, because, in the air it will be found, as with the omnibus service in our streets, that it is the short-distance traffic which pays, while the opportunity of getting a full complement of passengers is so much greater. As the business develops, we shall have the one machine confined to the one pilot in precisely the same way as locomotives are held day after day by the same driver, and the engineer and commander have control of the one liner. By prolonged association the pilot is certain to become thoroughly familiarised with his craft, to become intimate with its varying idiosyncrasies—to obtain the hang of it so completely as to become virtually part and parcel of the whole. In such way the utmost can be gained from an aeroplane as from any other vehicle. This serves as an additional inducement for the recognition of the zone and stage system of routes, because thereby it will be possible to extend the pilot the requisite "lay-off" after completion of a certain mileage. It must be remembered that, unlike other craft, the aeroplane cannot be liberally staffed. Each additional man carried represents the sacrifice of a passenger and the distribution of the possible earning-capacity of the eliminated passenger among those carried, which, if continued to an undue extreme, would inflate the carrying charges or fares to a prohibitive level.

So far as the short-distance traffic is concerned, the airship does not represent a serious competitor. It is essentially a long-distance machine. It will appeal for such business for reasons which are obvious from what I have related in connection with the description of the proposed trans-oceanic dirigible. But even here the stage system will need to be followed, owing to the adverse factor represented by a huge stock of petrol aboard. Seeing that approximately one ton

of petrol is consumed every 140 miles by a 60 knot 2,750 horse-power propelling unit at full speed, it will be seen that there are decided limits in connection with long-distance airship passages. The non-stop flight between London and New York would probably represent the limit in this connection, although, even in this instance it has been maintained that it would be preferable to follow a stage-to-stage route such as London — Iceland — Greenland — Newfoundland — New York, or London — Lisbon — Azores — New York, because there would be an appreciable volume of intermediate traffic, while the existence of the stations between would facilitate replenishment of fuel tanks.

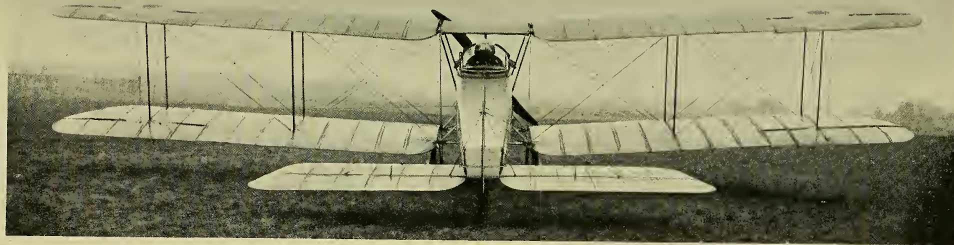
There is one aspect of the development of aerial travel which has not received the acknowledgment or encouragement it deserves. It is widely accepted that the airship routes will follow those of the steamship. This would be fallacious. By so doing it would come into direct conflict with its most formidable competitor—a rival able to offer far greater attractions to the traveller, and attractions which will induce him to pause and to reflect as to whether it is worth while going by air instead of by sea.

The airship will achieve its greatest success by opening up new routes, creating traffic, and incidentally developing trade expansion in new areas. If a five-day airship service were established between London and Australia, and airships were to sail every hour, it would not hurt the steamships plying between the extreme corners of the world by one cent. Paradoxical though it may seem, it would probably increase their returns, because it would stimulate trade between the two countries. The airship service would sow, although finding it extremely difficult to hold its own; and the steamships would reap the harvest. It would also come into conflict

with the cable service, which, seeing its revenue threatened from quicker transit of mails, would concentrate efforts to give better, quicker, and cheaper service, the ultimate upshot of which might easily lead the hustling commercial world to consider five days' communication too slow when a business transaction might be accomplished within a few hours by cheaper cable service.

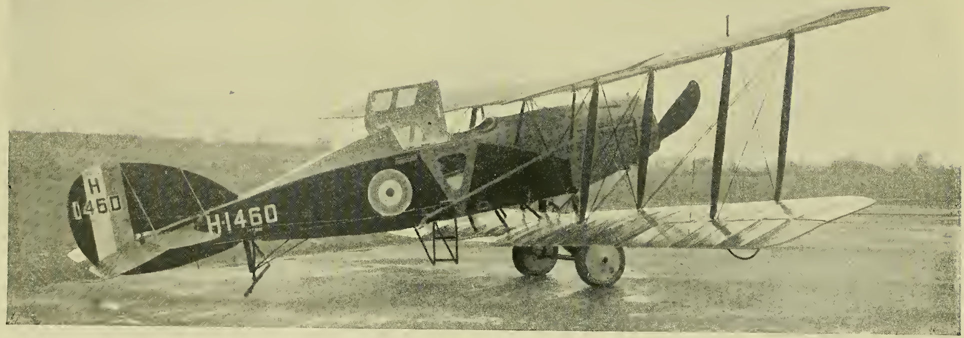
Plotting lucrative routes for both aeroplanes and airships will constitute an exceedingly difficult task, and many heart-rending failures will be recorded. It is work which will need to be conducted along daring pioneer lines, not conflicting with established services. It will be folly to judge results from the first spells of success. The novelty stage offers no index to the future; it is when the system settles down into its stride, occupying the particular niche in the scheme of things, which determines its future. But there are many corners of the world, the expansion of which is merely awaiting the introduction of some quick, frequent, and inexpensive means of communication. An aeroplane would flourish where a steamer, no matter how small and cheaply operated, would fail to earn enough grease to keep its engines running. These are the true openings for aerial traffic in its present stage; the openings which will enable development and evolution to be carried out to profit, and which, if conducted with sufficient enterprise and enthusiasm, must lead to the advance of the idea to such a stage of perfection as to allow its introduction to more competitive fields with every reasonable opportunity of success.

If the development of aerial traffic in the British Islands within the few months it has been opened, the period which should have been attended by the pressure incidental to novelty, offers any criterion of the future, then the prospects



THE LATEST TRIUMPH OF THE AEROPLANE BUILDER

The "Bristol" all-metal biplane, built expressly for use in tropical countries where wood is exposed to destruction by the white ant. There is a cabin for two passengers.



THE "BRISTOL" COUPÉ

Built upon the lines of the "Bristol Fighter" this machine is proving ideal for light fast traffic. It is being used by one prince of commerce for the conduct of business between London and the provinces

are decidedly disconcerting. We are decades removed from the day when the skies will be black with flying machines. With fares ranging from one shilling to five shillings per mile for the highest speed of travel combined with the lowest scale of comfort, the prospects are not encouraging. Even the millionaire demands a full return for his money, and he has never considered speed without a measure of luxury as equitable value for a high fare.

CHAPTER XIV

Some Typical British Aeroplanes of To-Day

TRANSPORTATION naturally falls under one of two broad headings. These are respectively passenger and freight. Of course these two classifications are capable of sub-division, especially freight, which can be split up into an almost indefinite array of classes varying with the character of the goods handled. Some are bulky but light, others are compact but weighty, still more are cumbersome and fragile, while there is also the extensive "perishable" category involving foodstuffs.

Passengers may be grouped under two fundamental headings. There is a certain proportion of the community which regards the time occupied in moving from one point to another as waste. This type of traveller bemoans the interlude because it cuts him off from his business, although the perfection of wireless telegraphy has done much to bridge this hiatus in commercial operations. Accordingly, this section, construing travel into an unavoidable evil, is prepared to accept the very swiftest means of conveyance available with a total disregard of cost. This is the class which favours the very fastest express trains, which will even incur the expense involved in chartering "specials" to save valuable minutes, which has brought the 25-knot liner into being, which enthusiastically supports extremely swift motor-car movement. But to them the high-speed aeroplane represents

a distinct move forward. The ability to travel at 120, 150, or, under favourable conditions of weather, at even 200 miles, an hour will be seized with avidity. Comfort during the journey is a secondary consideration; to these individuals it is far more important to be able to turn into a sleeping berth overnight in London and wake up the next morning in New York. They may be called upon to pay very heavily for the privilege of being carried at incredible velocity over 3,000 miles during the few hours when commerce is normally suspended, but that is immaterial. Business is business, and in the estimation of these individuals every available hour of existence ought to be surrendered to the conduct of that business. In other words, the exceedingly high-speed aeroplane is essentially for the supernal hustler, and he may be relied upon to support the development of this class of aerial craft.

The annihilate-time-and-distance members of the community, nevertheless, are in marked minority. The average individual is content to take travel more leisurely, even if it be identified with business. He regards the journey as a welcome break to the eternal round of commerce, appreciates comfort, and is not prepared to pay a fancy fare for his accommodation. This class outnumbers the former by probably a thousand to one, for the simple reason that it appreciates a certain joy in life, and knows that the human engine cannot be driven at sit-on-the-safety-valve pressure the whole while. Consequently, for this class of traffic, which is the more remunerative in the long run, a larger type of aeroplane will be necessary; one possessed of moderate speed but replete with every comfort, and with every disadvantage incidental to this system of movement reduced to the minimum.

This more slowly-moving majority of the community also

includes a considerable proportion of people who are quite content to tolerate relatively moderate luxury and comfort so long as they can secure the necessary passage at a low tariff; it is the class which is quite prepared to book a passage on the mixed passenger and freight steamship, making sundry calls on the way; and to this vessel it is immaterial whether any passengers be aboard or not because it is the freight which pays. For this reason we may safely anticipate commerce demanding an aeroplane of medium or low speed, capable of carrying both passengers and freight, or only freight, according to exigencies; but which, if passengers be included, will regard the latter only as an equivalent for so much freight from the revenue point of view.

Freight itself constitutes a much more complex problem—one which has not yet been fully investigated by commercial aviation interests. In this instance it will be necessary to evolve the very largest machine possible for a given horse-power, while speed will have to be reduced to the figure which yields the highest financial return. It will be the tramp of the air, ready to go anywhere, to pick up another load directly one has been dropped, thereby reducing the period of inactivity to the briefest possible, and to follow undefined instead of regular, carefully scheduled routes, that will be in demand.

Other classes of traffic, to which full reference is made elsewhere, are likely to prove highly remunerative and capable of extensive development. These include movement of light goods which can be packed in relatively small space, the urgency in delivery of which is paramount; the transport of first-class mails under certain conditions, and the urgent transmission of important dispatches. Certain grades of freight are quite impossible to the flying machine,

both airship and aeroplane, in the present status of the movement, for the simple reason that they are carried in bulk, time occupied in transport being virtually immaterial, and at exceptionally low rates. The time may come when the air will be able to compete successfully with movement by road, rail, or sea even in respect to these grades of freight, but it is certainly not within sight at the moment, and will not become a commercial practicability until we attain the mammoth craft propelled with engines of 25,000 to 30,000 horse-power.

Hard matter-of-fact commerce regards the situation more logically as contemporary practice plainly shows. Our manufacturers, settling down to peace conditions, are maintaining just sufficient imagination to keep progress moving, although they are pursuing a policy of "make haste slowly," the golden precept in all matters concerning transportation development as in other phases of human endeavour. Those firms which were pioneering the Way of the Air, especially in regard to the aeroplane, previous to the year 1914 have reverted practically to the point where their individual policy of evolution was interrupted by the outbreak of hostilities, although they are taking all the lessons taught by the war to heart in so far as they can be applied to decisive practical advantage. In certain phases of aerodynamic science the war has been productive of far-reaching knowledge, which has been fully assimilated, notably in matters concerning power, speed, lift and stability, and perhaps more particularly in regard to structural materials and their most efficient form.

It is my intention to narrate something concerning the latest developments in connection with the aeroplane and the adaptation of the destructive curses of war to the construc-

tive blessings of peace; and to tell of the machines, some of which, directly evolved from military models, have already established their commercial possibilities, because these craft are typical of the new or third era of aviation history. Possibly, in the *tout ensemble,* there may appear to be monotony of design, but this to a certain degree is inevitable, and is more apparent to the lay mind than real to the expert. On the other hand, in detail a striking manifestation of individuality and brilliancy of ingenious thought is manifest, while the modification of what may be termed well-standardised lines is probably more extensive than may be generally conceived.

The Bristol Aeroplane

Ten years ago—1910—the British attitude towards the Highway of the Air was decidedly apathetic. This indifference was not confined to the general public, but was incidental to manufacturing circles as well, while British inventive activity in regard to aviation appeared to be at a very low level. On the other hand, the French were pursuing investigation, experiment and research at a rare pace, the result being that their expressions of the solution to dynamic flight became familiar throughout the world. Farman, Blériot, and other French pioneers were in the full glare of the limelight.

However, in the above-mentioned year two enterprising and perspicacious British gentlemen, the late Sir George White, Bart., and his brother, Mr. Samuel White, impressed by the laurels which were being showered upon the French pioneers, the work of whom was promising to give our neighbour supremacy in the air, decided to establish the aeroplane manufacturing industry in this country. To this

end they founded the British and Colonial Aeroplane Company, Limited, establishing suitable works in which to carry out their intentions at Filton, Bristol. They were essentially business men, regarding the exploitation of the air exclusively from the commercial point of view, convinced that it must become a recognised highway for the conveyance of passengers and goods, while they were also sufficiently astute to realise that in war the flying machine must play a decisive rôle.

They accepted the Farman aeroplane as their model, intending to evolve therefrom, as knowledge of dynamic flight was acquired, a distinctive British type. How completely they succeeded is strikingly evident to-day. The Bristol aeroplane played a very prominent part in the aerial war, several hundred machines being built for the Royal Air Force, with which work of an incalculably valuable character was accomplished. The veil of secrecy which was necessarily maintained over our military operations reacted against the various machines designed and built at Filton from becoming known among the community at large, but they ranged from the "Bristol Scout," a single-seater capable of notching a speed of 140 miles an hour and of climbing to 10,000 feet in eight minutes under the energy developed by the 310 horse-power "Mercury" radial aero-motor, to the mighty "Bristol Triplane Bomber," to which the enemy was compelled to concede every respect. Not only could this craft carry a staggering load of heavy bombs, but, under the propelling effort imparted by its four Liberty engines, each developing 400 horse-power—1,600 horse-power in all—could attain a speed of 125 miles an hour.

War did not introduce the "Bristol" aeroplanes to the aerial arena; it merely served to assert the possibilities of

these machines and to vindicate the prevision of the two gentlemen who had been sufficiently daring to establish the new industry in these islands at a time when the conditions and public enthusiasm were at a depressingly low level. Within twelve months of commencing operations the French interests, who had had matters all their own way in regard to the exploitation of the Way of the Air, commenced to experience the effects of British competition. Bristol machines were flying in all parts of the world—from Italy to Australia, South Africa to Roumania, India to Spain, and were meeting with increasing favour in Russia, which, contrary to general belief perhaps, was one of the most progressive countries in those days in all matters pertaining to the development of the flying machine.

Activity was not confined to advancing the possibilities of the biplane. At that time there was a pronounced cleavage of opinion as to whether the monoplane or the biplane would offer the most attractive solution of the new conquest under way. The advocates of the monoplane pointed to the achievements of Blériot in support of their claims; the "biplanists," while conceding ungrudgingly due honour to the hero of the Cross-Channel flight, maintained that the most consistent flying was being carried out with the biplane, and that therewith, too, many triumphs had been recorded, especially by those most popular pilots the Farman Brothers. The sensational performances of the Wright Brothers were asserted to be an additional convincing proof of the superiority of this design.

The British company followed a generous policy. It took no sides in the controversy, but designed a distinctive "Bristol" monoplane which speedily won its spurs, not only in the Old, but in the New World. In fact, the monoplane

of British design and construction achieved such a high reputation as to arouse comment as to why this type of machine did not play a more prominent part in the war. As mentioned in another part of this book, the forces of prejudice proved to be incontestable. Even the French, who maintained a more enlightened and open mind, decided against the Blériot monoplane as a fighting unit, but this was solely due, so I have been informed, to technical military objections. The field of vision offered to the pilot manning this craft was declared to be so severely limited as to nullify its other accepted qualities.

Now that we have returned to peaceful conditions, permitting commerce to pursue its untrammelled way, what are the intentions of the Fathers of the famous "Bristol" creations? They are comprehensive, fully maintaining the progressive traditions of the company identified with the design and production of various models. We see the mighty Bristol triplane bomber "stripped of all the feathers of war." Death-dealing guns and destructive bombs have given way to a commodious body for the conveyance of passengers or freight. This massive machine in its peace paint has attracted widespread interest, for the simple reason that it is one of the most satisfactory of the large machines which so far have been evolved to meet the conditions of peace.

The two upper wings have a tip-to-tip span of 81½ feet, that of the bottom plane being 78¼ feet. The gap—vertical distance between the wing chords—is 7 feet 2½ inches, while the maximum chord is 8½ feet. The total wing area is 1,905 square feet. The area of the top fixed tail surface is 51½ square feet, while that of the bottom is 45 square feet. The top and bottom elevators each have an

area of 42½ square feet; the fixed rear fin surface 28·2 square feet, and the rudder 25 square feet.

The triplane is fitted with four "Liberty" engines, each developing 410 horse-power—1,640 horse-power in all—when running at 1,750 revolutions per minute. No reduction gear is incorporated, the transmission being direct to the two-bladed propellers, which consequently make a maximum of 1,750 revolutions per minute. The vessel measures 51½ feet in length over all, while its maximum height is 20 feet 8 inches. Its total weight, empty, is 10,650 lbs. —4¾ tons—and, fully loaded, ready for the air, including 450 gallons of petrol, 40 gallons of oil and 30 gallons of water, 17,500 lbs., or more than 7¾ tons. This gives a load for the total wing superficies of 8·65 lbs. per square foot, and a loading of 10·6 lbs. per brake-horse-power.

The engine power with which it is supplied is adequate to give the machine a speed of 125 miles an hour when flying near the ground, as, for instance, the altitude which would probably be generally attained in commercial practice when congenial atmospheric and meteorological conditions obtain. Its climbing capacity is also somewhat high, an altitude of 5,000 feet being attainable in 6 minutes, at which level it can maintain a maximum speed of 122 miles an hour. It can rise to 10,000 feet in 13 minutes and can notch a speed of 113 miles an hour at that altitude. Its lowest landing speed is 55 miles an hour.

This triplane, known colloquially as the "Bristol Pullman," from the circumstance that its military body has been superseded by a special Pullman car, has seating accommodation for 14 passengers, in addition to the pilot and engineer. Comfort and convenience have been closely studied, each passenger being provided with a luxuriously

upholstered arm-chair. The car, about 7 feet in height, is completely enclosed, and the seats are disposed on either side of a central gangway. For the convenience of each passenger there is a large square porthole glazed with triplex glass, while the pilot and engineer occupy a roomy cabin, glazed on all sides to offer a wide and uninterrupted field of vision, with lower portholes sweeping the ground in front and below, placed in the nose or prow of the body. Arrangements have been incorporated for heating and lighting by electricity, so that this aerocar offers all the attractions of the luxuriously embellished Pullman coach associated with the railway.

The passenger-seating accommodation is so arranged that any or all of the arm-chairs may be removed promptly if desired, to provide for stowage of luggage or general cargo. In this manner it is possible to obtain 320 cubic feet of space. In addition to the two pilots this triplane is capable of lifting a load of 2,700 lbs.—nearly 1¼ tons—with sufficient fuel for a four hours' flight, or, alternatively, 4,000 lbs.—approximately 1¾ tons—with fuel for a flight of 2½ hours. These figures are based on an economical speed, ranging from 100 to 105 miles an hour at three-quarter throttle, leaving a sufficient reserve of power to reach a maximum speed of 125 miles an hour, if necessary. However, taking the lower radius of action, it will be seen that this machine could carry about 1¾ tons of cargo between London and Paris, the air-line distance of which is 215 miles, the fuel capacity actually being adequate to carry this load a distance of 250 miles.

The British and Colonial Aeroplane Company has elaborated a second type of commercial vehicle, the "Bristol Coupé," which in many respects closely follows the lines

of the "Bristol Fighter," which proved such an eminently successful type of fighting machine. This is a biplane having a wing span, tip-to-tip, of 39 feet 3 inches, the chord of the wing being 5 feet 6 inches, giving a total wing area of 405 square feet. The machine has an all-over length of 25 feet 9 inches, while its maximum height is 10 feet 1 inch. It is fitted with a single Rolls-Royce "Falcon III." aeromotor developing 264 horse-power, driving a two-bladed propeller. In the empty condition the biplane weighs 1,750 lbs.; in running order, ready for the air, 2,300 lbs.

This coupé has been designed essentially for fast speeds, if desired, and at the same time is able to climb very rapidly. At ground level the maximum travelling speed is 130 miles, at 5,000 feet 127 miles, and at 10,000 feet 118 miles per hour respectively. It can climb, under fully laden conditions, to 6,000 feet in 5¼ minutes, to 10,000 feet in 11½ minutes, and to 15,000 feet in 21½ minutes respectively, while its landing speed is 48 miles per hour.

It carries a single passenger, for the comfort of whom there is a luxurious arm-chair placed in a totally enclosed cabin fitted with triplex glass windows on either side, thus affording complete protection against inclement weather and wind. Although the maximum speed is 130 miles an hour, it may be pointed out that it is not desirable to maintain this velocity for any considerable length of time. A cruising speed of about 100 miles an hour is preferable, inasmuch as this enables a marked economy in the fuel consumption to be effected. The fuel capacity permits a flight of approximately 400 miles to be made at 110 miles an hour at an altitude of 5,000 feet. If preferred, the machine can be employed for the conveyance of express mail or light cargo.

It is only necessary to remove the passenger's seat, which frees 23 cubic feet for this purpose, enabling a load of 450 lbs. to be carried, together with full complement of fuel.

This model has proved highly successful in operation. One gentleman, who is well-known in business circles, is utilising it to a considerable extent in the conduct of affairs between his London central house and provincial branches. To him the Way of the Air has made particular appeal, rendering him totally independent of the railways and roads, enabling him to carry out his transactions with the utmost expedition, which in his particular case is of distinct moment.

It has been suggested that the aeroplane will find a useful field of application in tropical countries, where competitive methods of locomotion are scanty and services indifferent. Doubtless this will prove to be the case, but probably many of the enthusiastic advocates of this application have overlooked the fact that the machine will demand to be specially built for such duty, and that it will be dangerous, if not impracticable, to rely upon wood as a structural material. The penchant of the white ant for wood must not be forgotten. The manufacturing organisation at Filton has been devoting especial study to this possible application, and, accordingly, some time ago set out to design and build an all-metal aeroplane. The suggestion is by no means new, because the question of the all-metal dynamic machine has been discussed academically for some years past, but the British and Colonial Aeroplane Company is the first to carry the idea into practical effect. This represents further pioneering, because the substitution of the familiar and generally accepted wood by metal has involved new designs

and calculations as well as the solution of other technical problems. Nevertheless, the "Bristol" all-metal biplane has convincingly proved the practicability of the idea and that it can be carried into practical commercial effect without appreciably adding to the weight of the machine. Tests have also revealed the fact that performance is in no way affected by such a deviation from the generally accepted practice. Apart from the fact that an all-metal machine—the wings, of course, are excepted, investigation not having yet succeeded in replacing fabric by metal—extends many advantages, the most salient of which are increased durability and enhanced security from fire, it is also more readily applicable to violent extremes of climate, such as the intense heat of the tropics and the severe cold experienced in the polar regions.

Metal is used throughout. The component parts of the wings—edges, spars, ribs and so on—are built up of aluminium and high-tensile steel, the dimensions of which have been modified to meet the new conditions. The interplane and other struts are of high-tensile steel, while the fuselage is a special construction of aluminium and thin steel. The use of metal imparts a more slender *tout ensemble,* from the ability to decrease the dimensions of the visible members, such as the interplane struts and the under-carriage, but symmetry of form and gracefulness of line are fully retained if not actually enhanced.

This model has a tip-to-tip wing span of 42 feet 2 inches and a wing chord of 6 feet. It is fitted with a single "Viper" Hispano-Suiza aeromotor developing 170 horse-power, giving the machine a maximum speed near the ground of 105 miles an hour. The over-all length is 27 feet, while the maximum height is 10 feet 3 inches. Empty, the

machine weighs 1,700 lbs., while loaded and ready for service the weight is 2,870 lbs. The wing area is 458 square feet, the loading thereof being 6·13 lbs. per square foot, while the loading per brake-horse-power is 16½ lbs.

The machine is able to climb to 5,000 feet in 8 minutes and occupies 20 minutes to rise to 10,000 feet. At the former altitude the speed is 100 miles per hour, while at 10,000 feet it is 93 miles per hour. However, the economical cruising speed at 5,000 feet is 85 miles per hour, at which speed the fuel capacity is sufficient to enable a non-stop flight exceeding 500 miles to be made.

Seating accommodation is provided for two passengers in addition to the pilot. For the former is a roomy cabin completely enclosed to assure full protection from the weather. For sight-seeing purposes glazed windows of safety glass are provided. Here, again, if desired, the passenger accommodation may be removed to permit the machine to be used for the conveyance of mails or light cargo, the available space being approximately 40 cubic feet. In addition to the pilot a useful load of 450 lbs. may be carried.

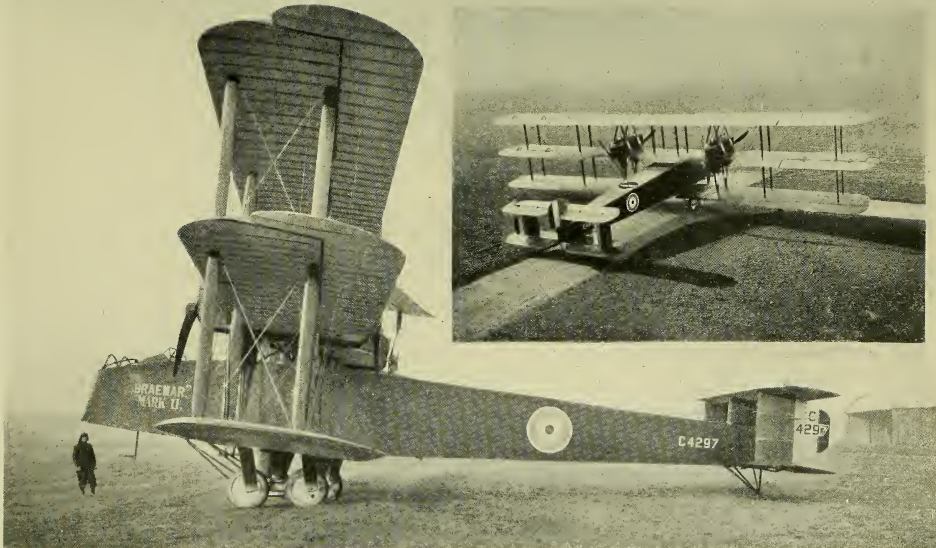
The foregoing by no means exhaust the commercial proposals of the company in question. Other "Bristol" models have been elaborated to meet varying requirements, and in the preparation of these designs vital factors of running and maintenance charges have been carefully studied. Some of these designs have been so advanced as to permit construction to be taken in hand the moment commercial exigencies demand, and to meet any particular phase of development which may arise. Those described in detail, however, represent the contemporary producing

activity for the world of business and are proving highly satisfactory in operation from every point of view.

The Martinsyde Aeroplanes

Another firm of aeroplane builders, which formed one of the small army of pioneers who sought to popularise not only flying in Britain but domestic construction during the apathetic days of a decade ago, is that whose fortunes are identified with the Martinsyde machines, built at Woking, in Surrey. A short time previous to the cessation of hostilities the enemy found himself harassed by a new and "nippy" super-fighting scout, which taxed his counter tactics in the air to no mean degree. This was the Martinsyde "Buzzard." It created a sensation owing to its speed, climbing qualities, and power of manœuvre.

Subsequent consideration pointed to the fact that, by carrying out certain slender modifications, this machine might be rendered exceedingly attractive for certain phases of commercial or pleasure flying. The modifications in question are confined to specific details, because it would be difficult to imagine a more trying test for a flying machine than that of scouting over hostile territory where the enemy's defensive measures, both from the ground and in the air, are naturally encountered in their most formidable form. Consequently, so far as structural considerations are concerned, this machine has suffered no alteration. Being of exceptional strength and high speed, it can be flown safely under any atmospheric conditions and can bid defiance to the wildest storms. For this reason it will appeal to the skilled and experienced aviator, drawn to the air from sheer love of flying, or who, owing to business exigencies, finds it imperative to cover long distances in the shortest space of



THE "BRISTOL TRIPLANE" AS A PASSENGER AND CARGO CARRIER

As a Pullman with accommodation for fourteen passengers, the "Bristol Bomber" will fulfil a far-reaching mission in peaceful trading. This huge machine has an over-all height of 20 feet 8 inches, and a speed of 125 miles an hour. Inset shows the triplane from the rear, giving an impressive idea of its dimensions and graceful lines.

time, irrespective of meteorological conditions. To the sporting aviator it will make especial appeal, as it will be found to offer him all the delights he can possibly desire, and enable him to carry out those "stunts" in which, under war conditions, he possibly excelled "On Service."

This quondam motor-driven pugnacious hornet is known in its new form as the "Sporting" Martinsyde. It is a single-seater with its remarkable high speed factor fully maintained, both in regard to straight flight and climbing prowess. It is a small biplane, having a tip-to-tip wing span of 32 feet 9 inches, an over-all length of 25 feet 6 inches, and height to tip of two-bladed propeller when vertical, of 10 feet 4 inches.

It is fitted with a Rolls-Royce "Falcon" 280 horse-power motor, and the carrying capacity, over and above fuel supply for 2½ hours continuous flight, which is sufficient to cover approximately 300 miles, is 350 lbs. The flying capabilities of this machine are certainly startling, as may be gathered from the following details:

Maximum	speed at	10,000 ft.,	142½	miles	per hour.
,,	,,	15,000 ,,	136½	,,	,,
,,	,,	20,000 ,,	126	,,	,,

Its climbing speeds are not less striking as may be realised from the time occupied in gaining the following altitudes from the ground, these being:

Climb to	6,000 ft.	3 mins.	40 secs.	= 1,636.3	ft.	per minute.
,,	10,000 ,,	6 ,,	40 ,,	= 1,500	,,	,,

Accordingly, the owner of this machine secures as complete a command of the air as he can possibly desire to gratify his sporting proclivities. For normal purposes,

however, the cruising speed would probably prove more attractive, if only for the economy in petrol consumption it offers. Still, this approaches a velocity of 2 miles a minute at 5,000 feet altitude, being, at two-thirds full power, 110 miles an hour. The machine lands easily at 45 miles an hour. It was this single-seater biplane which established the Paris—London sensation flight by covering the 215 miles between the two capitals in 75 minutes—an average speed of 180 miles an hour—*a mile in twenty seconds!*

In striking contrast to the sporting model is the Martinsyde "A" commercial aeroplane which conforms more closely with the prevailing interpretation of a biplane designed and built for the requirements of passenger and freight traffic. As a passenger-carrier it has accommodation for three, four, or five passengers according to requirements, while, when devoted to the utilitarian duty of cargo-carrier, it is able to transport nearly one ton of freight.

The over-all span, tip-to-tip of wing is 43 feet, while the machine measures 27 feet 4 inches from end to end. The height to tip of propeller is 10 feet 10 inches. The aeromotor is either a Rolls-Royce "Falcon" or "Eagle" according to the proposed class of traffic, the former being advocated for passenger, and the latter for cargo-carrying duty respectively, though, of course, if preferred, either engine can be installed to meet the requirements of mixed traffic. With the former aeromotor, however, the carrying capacity is 1,800 lbs., while the latter and more powerful engine enables a load of 2,240 lbs. to be carried; but, no matter which aeromotor is used, the radius of action is identical, namely, six hours' continuous flight at a cruising speed of 100 miles an hour, which represents two-thirds of the power available.

If fitted with the "Falcon" engine the machine would

be able to carry, in addition to the pilot, from two to four passengers, according to the weight and quantity of attendant luggage or load. Of course, if used solely as a cargo-carrier the seating accommodation would be dispensed with, the whole of the space being released for freight, while for mixed traffic only part of the passenger accommodation would be removed. This biplane has been designed essentially for commercial purposes, and although its travelling speed is high, even at two-thirds full power, it is not endowed with sensational climbing powers. Nevertheless, it can climb at the rate of 500 feet per minute with full load, while the landing speed is low, being between 35 and 40 miles an hour.

This is the type of machine entered for the trans-Atlantic flight from Newfoundland to England, with Raynham at the wheel, which met with an unfortunate train of mishaps before rising into the air, leading to the ultimate abandonment of the journey. For the purposes of this 1,880 miles' continuous flight a special and very large tank was fitted into the space normally provided for the stowage of cargo, the fuel capacity of this reservoir being adequate to enable the machine to remain aloft for 25 hours at the cruising speed of 100 miles an hour, leaving a reserve of speed of 27 miles an hour, since it is able to notch 127 miles an hour with the engine all out.

What might be described as a compromise, or "Between Model," is the Martinsyde two-seater, or single passenger carrier. In reality it is a miniature of the commercial type, most of the parts being interchangeable therewith. The fuselage is so built as to accommodate both pilot and passenger comfortably, ample protection for both being extended, while, if desired, the passenger's cabin may be

completely enclosed. Travelling and climbing speeds are approximately the same as those of the sporting model already described, and it will appeal to the man in a hurry, and will be found to meet those occasions when "air-haste" travel is imperative. The biplane is equipped with a Rolls-Royce "Falcon" engine, the duration of the flight or endurance being set down at approximately 4½ hours, during which time it will cover about 500 miles.

The Boulton-Paul Aeroplanes

Among the machines which were created directly by the war and which proved to be surprising from the startling character of their performance must be mentioned those which were designed at, and which issued from, the Norwich aircraft works of Messrs. Boulton & Paul, Limited. One, the "Boulton Bourge" gave a somewhat remarkable demonstration at Hendon. A twin-engined biplane, with a wing span of 54 feet, weighing with full load 6,000 lbs., and having a maximum speed of 124 miles an hour, it is able to loop the loop, side roll, spin—in short, it can fulfil all the evolutions which are generally held to be possible of regular performance only by the small fighting scouts. This "stunt" capacity is due to the strikingly efficient design of the machine, enabling it to withstand all the severe strains involved in the execution of such manœuvres.

This eminently successful machine has now been reproduced in a broadly similar commercial form, although the peace model is somewhat larger in all dimensions, heavier, of greater carrying capacity, and has a higher turn of speed. It is a twin-engine biplane with a wing span, tip to tip, of 59 feet. The chord of the top wing is 8 feet and of the bottom wing 6 feet, the wing area being 770 square

feet. The over-all length is 40 feet, while it is 12 feet 4 inches in height. The power installation comprises two Napier aeromotors, each developing 450 horse-power. Its total weight, empty, is 4,000 lbs., while fully loaded, ready for flight, it weighs 7,000 lbs. — a little in excess of three tons.

Its travelling and climbing speeds are somewhat striking, especially the former, because, with full load aboard, it is able to reach a maximum of 149 miles an hour at 10,000 feet and 142 miles an hour at 15,000 feet, its ascensional limit or "ceiling" under these conditions being 25,000 feet. When fully loaded this biplane is able to climb to 10,000 feet in 8 minutes, and to 15,000 feet in 15 minutes—1,250 feet and 1,000 feet per minute respectively. The landing speed is 54 miles an hour, and radius of action, upon the one fuel charge, is 3 hours' continuous flight.

This machine is designed to carry eight passengers and half a ton of mails. It was entered for the trans-Atlantic flight, the passenger compartment being stripped in order to receive additional petrol carrying tanks. By this arrangement sufficient fuel was stowed aboard to carry the machine 3,800 miles, or a non-stop flight of 32 hours' duration at an average speed of approximately two miles a minute. The trans-Atlantic crossing, however, was abandoned following the sensational journey of Sir John Alcock.

Another commercial aeroplane which has been designed by this company, the "Busibus," is of quite a different character. It is a single-engined two-seater biplane the wing span of which is only 25 feet from tip to tip, the chord of the top and bottom wings being 5 feet, and the total wing area 255 square feet. It is less than half the size of its big brother, the over-all length being 19 feet, while it is only 8 feet in

height. In the empty condition it weighs 1,000 lbs.—less than half a ton—while with full load aboard, and in running order, ready for proceeding aloft, it weighs 1,460 lbs., which is well below the 14 cwt. mark.

In the fully-loaded condition it climbs to a height of 5,000 feet in 9 minutes. At an altitude of 1,000 feet under the same weight conditions it has a speed of 103 miles per hour, while it can remain aloft for 2½ hours on one full charge of the tanks. The landing speed is comparatively low, being 45 miles per hour.

This machine is designed for what may be described as limited commercial service. It is relatively cheap, costing complete only £600. It might almost be described as the aerial counterpart of the runabout motor-car, and will prove eminently serviceable for cross-country travelling, where the road services are notoriously infrequent and slow, and also for duty in sparsely settled territories, the communities in which are somewhat isolated. It is likely to make appeal to those who are disposed to indulge in pleasure flying upon a limited scale, for private service, or for single passenger commercial journeys—the aerial taxi-cab of the countryside as one might perhaps term it. As an indication of what may be done in this direction, by way of the air, the builders of this handy little machine use one to travel across country when it is necessary for a passenger to make a certain town or other centre as quickly as possible, and which otherwise is not possible of access except by a roundabout or prolonged and tedious railway journey. As a matter of fact, for short distance journeys of this character, where time is a consideration, there is a decided opening for the small, easily-handled aerial runabout, of which the "Busibus" may be said to be an attractive illustration.

Typical British Aeroplanes of To-Day

The "Vimy" Aeroplane

Undoubtedly the aeroplane which caused the greatest sensation during the year 1919 was the "Vimy," emanating from the Weybridge aeroplane works of Messrs. Vickers, Limited, the well-known armament manufacturers and shipbuilders. It burst upon commercial aviation circles in a startlingly dramatic manner by crossing the Atlantic at an average speed of nearly two miles a minute. It startled the world for the simple reason that it was an unknown quantity, practically nothing having been heard of the machine previous to this remarkable achievement. The "Vimy" was one of the surprises of the war, numbers having been built for, and supplied to, the authorities once it had established its possibilities and performance, its designed purpose being long-range bombing.

This machine has also served to bring home to the world at large the beneficial and upbuilding, or sinister, duty to which the dynamic flying machine can be applied as conditions demand, and with what promptitude an aeroplane can be transformed from one range of service to the other. In other words, it emphasises how an aeroplane flying to-day, bearing passengers and merchandise upon a peaceful mission, can be converted into a deadly weapon of destruction within an hour or two—that the aeroplane is really a military unit in commercial garb. To effect the transition it is only necessary to change the body, an operation that can be effected very quickly if so made as to be interchangeable. But unless this interchangeability constitutes an outstanding feature conversion is likely to prove a somewhat dangerous practice. From this it is apparent that the aeroplane to be of real national utility must be built for the one service, notably

military duty, and be used for the other or commercial use.

This is the theory which at present obtains in certain circles; whether it will be substantiated in actual practice remains to be proved. The only analogy which can be drawn to this particular line of thought is in connection with the high-speed ocean liner, held in reserve to be converted into an armed cruiser when the emergency arises, but in which application, as experience has proved, it has distinct limitations. Whether the same will apply to the air it is as yet impossible to say. At the moment the aeroplane as a weapon of attack has gained the ascendancy over defence, but now that the study of the latter problem in its military aspect and in all its bearings may be conducted at leisure, with more concentration of thought, it is not improbable that the present state of affairs will undergo a complete reversal and bring home the fact that an aeroplane for war service must be of special design and construction to enable it to withstand all and every aerial opposition which it is likely to encounter. This is an issue which time alone can prove. Sufficient for the moment is the knowledge that the "Vimy" aeroplane is fundamentally a military arm, and that the sole modification between the "Vimy" bomber and the "Vimy" commercial flying machine rests with the fuselage.

The significance of this interchangeability of the body is reflected in both the "Vimy" commercial and trans-Atlantic models, and being both transformed bombers, they are practically identical. Consequently the description of one applies to the other. The tip-to-tip wing span is 67 feet, gap 10 feet, and chord 18 feet 6 inches. From end to end the machine measures 42 feet 8 inches, while the over-all height is 15 feet 3 inches.

This biplane is of the twin-screw type, the propelling effort being imparted by two Rolls-Royce "Eagle" Mark VIII. engines each of 375 horse-power, giving a total output of 750 horse-power. Should one engine give out completely the machine can be kept going at a speed of 70 miles an hour with the other. The maximum speed is 100 miles, cruising speed 90 miles, and landing speed 45 miles an hour respectively. Sufficient petrol is carried to permit a continuous non-stop flight of five hours, but should an increased radius of action—endurance as it is termed in aero language—be required, it can be secured by fitting extra tanks. The factor of safety is 5, which means that the machine has been so designed and built as to secure five times the strength really necessary for normal flying conditions.

One interesting feature of the "Vimy" commercial fuselage is the novel principle of its construction, which is totally different from that usually practised. It is built upon what is known as the "Monocoque" system. Instead of the body being built up in the usual manner, the shell of the cabin is attached to oval wooden rings of box section. These rings are of three-ply wood, are very light, but at the same time of immense strength. The shell, or cover, forming the cabin is made of what is described as Consuta patent, an entirely new principle superseding three-ply, and is the speciality of Messrs. S. E. Saunders, Limited, the well-known boat builders of Cowes, Isle of Wight, who are now allied with the Vickers Company. Thus it will readily be recognised that the building of the car of the aeroplane is becoming recognised as belonging to the boat-building craft, which is not so surprising, seeing that immense strength is required with lightness and that the form of the body should offer as slight resistance to the air as does the boat to the water.

This principle of fabrication entails the employment of the use of thin layers of selected wood, the grain being placed diagonally. They are glued and sewn together, the rows of stitching running parallel and spaced about 1½ inches apart.

Owing to this material being extremely strong a high factor of safety is given to the whole construction of the cabin. Moreover, it enables cross-bracing wires, such as are essential to the usual form of fuselage, to be dispensed with entirely, and the absence of these stays adds very materially to the comfort of the passenger accommodation. There is another advantage accruing from this departure from general practice. The cabin being like a boat, the machine, if forced to the water, will float on an even keel. The water cannot penetrate the cabin, since the doors are so made as to be completely watertight. Consequently the requirements of "Safety first," so imperative in matters pertaining to aeroplane construction to secure the confidence of the public, and to which I have made extended reference in another chapter, is appreciably enhanced. With the ordinary aeroplane, as distinct from the seaplane, which is equipped with floats instead of a wheeled carriage, a forced descent upon the water is viewed with misgivings by the pilot, inasmuch as the machine is likely to be lost; at all events, the fuselage becomes untenable because it suffers submergence. For this reason a cabin so built as to present the property of floating for an indefinite period is certain to meet with wholehearted appreciation by those who have to go up to the air in aeroplanes. Two pilots are carried on this craft, seated side by side, the cock-pit being placed up high in the nose, from which point a wide range of vision is assured.

The cabin is completely enclosed. There is seating capacity for ten passengers, the arm-chairs being disposed

on either side of a central gangway. There is also ample space between the seats so that the passengers are not crowded in any way. As a matter of fact the commodious cabin accommodation of the "Vimy" commercial flying machine constitutes an outstanding feature. At one end of the cabin cupboards are provided for the reception of light hand-luggage. A window is conveniently placed to each seat, so that the passenger is able to secure a sweeping view of the earth beneath from the comfort of the arm-chair. Those who are interested in the latest conditions of travelling, who may be somewhat curious to learn at what height and at what speed they are travelling, will find the height and speed recorders prominently displayed in the cabin a source of interest. Ventilation and heating can be adjusted to meet the temperature conditions prevailing, while special arrangements have been incorporated to deaden the noise and to eliminate vibration. A final touch of completeness is imparted by the provision of telephonic communication between the passengers and the pilot.

While this vessel has been primarily evolved for the conveyance of passengers, it can be readily and promptly converted into a freighter or adapted to any other desired phase of industrial duty. The arm-chairs can be detached and removed in a few minutes, and when this is done the cabin presents a clear floor area of 53 square feet and a measurement space of 300 cubic feet. Within this space can be stowed 2,500 pounds, or a little more than 1 ton, of cargo, which can be kept quite dry and at an even temperature.

It is maintained in many quarters that the aeroplane, the moment it establishes its reliability in the commercial sense, will be used extensively for the carriage of a certain class of mail—express letters and parcels. To stimulate the

adaptation of the aeroplane to this duty, and to enable it to compete with the accepted mediums for the transport of postal matter, the cabin can be equipped with sorting-boxes, thereby permitting the mail to be sorted en route along the lines followed in the travelling post offices attached to our railway trains. Arrangements have also been introduced to permit the dropping of mail-bags where necessary between terminal stations by the aid of parachutes.

The "Vimy" aeroplane which successfully flew the Atlantic at 117½ miles an hour was identical with the commercial type except for one or two slight modifications necessary to equip it for a journey involving such an exacting test of endurance. The capacity of the petrol tanks was increased to 865 gallons and of the lubricating oil tanks to 50 gallons. In this way the radius of action upon the one fuel charge was increased to 2,440 miles—a margin of approximately 30 per cent. in excess of the actual air-line flight, which was 1,880 miles. It was anticipated that an average cruising speed of 90 miles an hour would be maintained, this being an economical speed in relation to fuel consumption, in which event the journey would have occupied about 21 hours, and accordingly the successful crossing of the stretch of open ocean in 15 hours 57 minutes, at a speed approaching 2 miles a minute, was decidedly sensational.

The "Vimy" contestant for the £10,000 prize offered by the *Daily Mail* for the first direct flight across the Atlantic shot up from the flying ground at St. John's, Newfoundland, with Captain John Alcock, D.F.C., at the wheel, accompanied by Lieutenant Arthur Whitten Brown as navigator at 4.28 Greenwich mean time on the afternoon of Saturday, June 14, 1919. It was a daring start because the

wind was blowing at 40 miles an hour; but seeing that it was due west, and so was behind the machine, it was decidedly favourable once the aeroplane had risen into the air. At the time the ascent was made the aeroplane weighed 5 tons, 3½ tons of which was represented by the fuel and lubricating oil. Gaining flying speed, a quick climb to 1,000 feet was made, and once the navigator had determined the course the engine was throttled down, the wind being in her favour, and she was allowed to climb as she liked, in this way notching a height of about 4,000 feet by nightfall.

The journey was as exhilarating as one could desire. The machine assumed a level between two superimposed layers of clouds, one bank scudding along 2,000 feet above the water and the other drifting at 6,000 feet. Consequently sea, horizon and sun were blotted out during the evening and the stars and moon after darkness had fallen, rendering it impossible to check the course by observation with the sextant. Accordingly the navigator had to rely upon dead reckoning. It was not until the machine had been travelling for nearly eight hours that a glimpse was caught of Polaris and Vega, and although the clouds only opened up for a few seconds the interval was sufficiently long to permit the navigator to take a reading by the stars and to determine the extent of drift, which up to this point had been an *x* quantity. The course was now checked and adjusted in order to bring the machine on the line which had been plotted upon the chart.

In the grey murky dawn the aeroplane ran into a thick bank of fog, and this proved to be the worst stretch of the whole journey. Snow, rain and sleet were encountered in fitful turns, and the temperature being low the speed indicator was thrown out of action through becoming jammed by the ice

which settled on it, the last reading it gave before breaking down being 90 miles an hour. Owing to the fog being impenetrable and all sense of horizon being lost, the aviators were now the sport of the forces of Nature, and, according to their own impressions, some unexpected evolutions were performed, including inadvertent looping of the loop, steep spiralling, and a sharp nose dive which brought the machine perilously near the water. The passing glimpse of the grey sea gave the pilot his horizon once more, though when it was gained the machine was lying on its back, having turned over unknown to the aviators, which, by the way, is a very common trick of the aeroplane when flying in dense fog. The sudden descent, however, had not been an unmixed blessing. It released the speed indicator of the icy shackles which had been holding it fast, and thus resumed its normal function. A quick climb was made to 6,000 feet, where another fog bank was encountered. The pilot decided to get above this and so ascent was continued, an altitude of 11,000 feet ultimately being reached, but not the top of the cloud bank, which at that point was from 2 to 3 miles thick. But hail and snow were encountered, covering the machine with ice.

The conditions well up not being at all favourable, another descent was made, the machine coming to within 300 feet of the water. But no sight of the sun was caught, no glimpse of a passing vessel, while the air was uncannily silent, inasmuch as no wireless messages were received although there was a wireless equipment aboard. After ploughing through this thick weather, along a switchback course, a dark cloud was descried on the horizon about nine o'clock on the Sunday morning. It loomed up suddenly out of the fog. A second hurried glance sufficed to confirm the

aviators that they were approaching the coast of Ireland. Then the slim, lofty masts of the Clifden wireless station were descried, were circled, and the machine brought down in a bog, which from aloft seemed as stable as any green meadow ever could be. The landing was made at 8.40 a.m. Greenwich mean time Sunday morning, June 15th, 1919. The direct flight across the Atlantic had been accomplished, and the £10,000 duly and deservedly won.

Although this did not represent the first crossing of the Atlantic by air, the American aviator, Lieutenant Commander Read, U.S.N., having completed the journey fifteen days previously in stages by way of the Azores and Lisbon to Plymouth, occupying nearly 16 days in the effort, to ensure which elaborate precautions had been taken, the Alcock-Brown flight with the "Vimy" was far more remarkable. Not only did it represent the spanning of the tempestuous Atlantic as the bird flies, but the mileage covered between the Old and New Worlds in the non-stop flight was greater than the longest lap on the Azores route, which was 1,381 miles between Trepassey Bay, Newfoundland, and Ponta Delgada, Azores. Thus the northern flight was 499 miles longer, while the tax imposed upon the machine and also the physical endurance of the aviators was far more excessive owing to the extremely adverse climatic conditions ruling over the North Atlantic.

The Avro Aeroplane

The French ushered in the era of commercial flying with the aviation meeting held at Rheims in 1909, which attracted crowds from all parts of the world. Britain was not far behind, a similar attraction being held shortly afterwards at Blackpool, at which one British experimenter made a bold

bid for recognition. This was Mr. A. V. Roe. He appeared with a triplane which created intense interest, though scarcely in the manner anticipated by the creator. The machine capered upon the ground in a furious manner, and appeared to be so dangerous as to be promptly and facetiously nicknamed "The Yellow Peril" by the crowd, which became highly amused at its efforts to fly.

But the indefatigable British pioneer exacted a revenge, and became proof against banter and ridicule; he rose supreme to difficulty. To-day there are few machines so familiar to the man in the street as the "Avro" biplane, and it certainly has earned a distinctive reputation. When war broke out it was found that, by virtue of his dogged perseverance, Mr. Roe had contrived a design which was discovered to be wonderfully correct. In the days when we were weak in the Third Arm, the authorities were compelled to acknowledge the work of an inventor who had been relentlessly ridiculed, and whose run of luck has been notoriously unfortunate. The Avro biplane was used for bombing, fighting, reconnoitring—in short, every military purpose. It was a wasp of this type which sealed the fate of one of the mighty Zeppelins in which the Germans had placed such implicit trust, while it was also this type of craft which undertook the momentous raid upon the Zeppelin sheds at Friedrichshafen during the early days of the war.

When the authorities realised that aeroplanes would be required in the thousands, and that it would be necessary to raise pilots by the tens of thousands, the question of training fighting bird-men aroused earnest consideration. Naturally, from the delicacy and danger of the work, a machine of indisputable reliability would be required. Survey demonstrated that the formerly much-maligned and bantered

The "Boblink" small fast passenger-carrying plane, which served as a fighting scout.

The heavy passenger-mail carrier, with a seating accommodation for eight passengers and half-a-ton of mail, having a maximum speed of 149 miles an hour—a remarkable heavy twin-engine biplane.

The "Busibus" two-seater, costing £600, adapted to fast cross-country and short-distance travelling.

THE BOULTON AND PAUL COMMERCIAL AEROPLANES

but war-tried Avro biplane was best adapted to this exacting duty.

Forthwith the machine in question was withdrawn from the fighting arena and utilised exclusively for training purposes, becoming the sole school machine of the Royal Air Force. It was eminently adapted for this vital phase of service. It is, above all things, stable and safe, easy to fly, while the dual control materially facilitates the task of the instructor. Moreover, it is an ideal machine wherewith to master the mysteries of aerobatics. Certainly there were an unfortunate number of accidents during training, but the cause was generally attributable to the excessive zeal of the pupil, naturally disposed to take extreme risks, rather than to the machine. With a less reliable craft the casualty list would have been much longer, and if the roll be considered in comparison with the number of flights made, the results are certainly favourable to the machine. Some idea of the demand which was imposed to satisfy official training requirements may be gathered from the fact that this machine was built in far greater numbers than any other aeroplane in the world. Altogether 10,000 Avro biplanes were built and supplied to the R.A.F. during the war.

Upon the initiation of the civil flying era in Britain, the Avro made a bold bid for popular favour. Joy-riding was introduced at our popular pleasure resorts, and it is the Avro which has attained the highest degree of appreciation in this connection. "Joy-flying" was a great attraction during the "peace" (1919) summer season at thirty of our leading pleasure centres, Hounslow and Blackpool being the most notable. In this application the Avro has repeated the performance for safety and reliability which it achieved during the war: upwards of 20,000 passengers having been treated

to the novel experience of aerial travel during the first three months following the inauguration of these novel services, which have done much to educate the uninitiated public to the claims of the Way of the Air.

The Handley-Page Aeroplane

Probably few large aeroplanes are so familiar to the residents of the City of London and the Home Counties as those issuing from the Handley-Page aerodrome. It may truly be described as the Condor of the air in so far as the artificial birds are concerned. What is probably the most remarkable feature concerning this vessel is that war exercised but little influence upon its design except towards the "colossal." It was found to be eminently adapted for a certain range of duty, and was reserved for that work. And the type which became standardised as it were to meet the needs of war is being similarly standardised to satisfy the calls of commerce, the only modifications of moment introduced being the substitution of the necessaries of peace for those associated with war. These machines are most impressive from their huge dimensions. They may not be so fast as their smaller brothers—mosquitoes of the air—but what they lack in speed is more than counterbalanced by their carrying capacity, which is high.

The twin-engine or smaller biplane, which was reserved for carrying out night-bombing operations, has a tip-to-tip wing span of 100 feet. Its over-all length is 63 feet, while it is 23 feet in height. In the empty condition it weighs 8,000 lbs., and 14,000 lbs. fully loaded with petrol, oil, pilot, and passengers. The useful load, either of passengers or cargo, is 4,500 lbs.—two tons. There is accommodation for twelve passengers in comfort, while eight more, making

twenty in all, can be carried if necessary. The seating arrangement, however, is for fourteen persons, that is according to the latest machines such as have been dispatched to China.

The propelling equipment comprises two 12-cylinder Rolls-Royce "Eagle" aeromotors, each developing 350 horse-power, a total propelling effort of 700 horse-power. Sufficient tank capacity is provided to receive 300 gallons of petrol, 150 gallons in each of two tanks. In the commercial type the arrangement of the tanks is somewhat interesting. They have been removed from the fuselage to be mounted in line with and behind each of the two aeromotors, each engine and its tank thus forming one complete unit. The tank is made to coincide with the over-all width and height dimensions of the engine, so as to be enclosed in the one cover, and is given a pointed stern. This arrangement imparts to the driving unit the appearance of a large torpedo, but at the same time enhances the symmetrical and graceful general appearance of the biplane. While the tank is placed only a few inches abaft the aerometer it is fully protected from the heat radiated from the latter by means of a substantial dividing wall, or partition, of asbestos, so that all danger from fire is completely eliminated.

The petrol consumption of the twin-engine craft ranges between 40 and 50 gallons per hour, which is adequate to give a non-stop endurance ranging from 6 to 7½ hours. The maximum air speed is 95 miles an hour, though the touring air speed is 85 miles an hour. Should one engine break down the biplane is able to continue flight, though at a reduced speed, on the other aeromotor.

Practically the whole of the interior of the fuselage is converted into a saloon for passengers. The diagonal brac-

ing wires have been removed in favour of substantial V-struts. In this way not only is more free space provided for passengers, but the machine itself is appreciably strengthened. The seats are disposed on either side of a central gangway, while communication between the ground and the saloon is afforded by a door set abaft the engines. The depth of the fuselage at all parts is adequate to permit the tallest passenger to stand upright with ease, there being plenty of headroom, while ample natural illumination is afforded by side windows conveniently placed beside the seats allowing the occupants a wide view from the comfort of their seats. Electric lighting and heating amenities are also provided. Owing to the large dimensions of the machine there is no discomfort from vibration when in the air, the biplane while in flight being as steady as a rock.

The load or passenger carrying capacity of this machine was first demonstrated in July, 1916, in the course of which 21 passengers were carried to a height of 7,000 feet over London. This was the aeroplane which flew from London to Constantinople and back in 1917, bombing the Turkish capital and the disabled *Goeben*. The machine carried three officers and two mechanics, together with baggage, bedding, tools, spare parts, including two four-bladed propellers, the total weight of the machine thus loaded being over six tons. The flight of 2,000 miles involved crossing mountain peaks ranging from 8,000 to 10,000 feet, though the bombing of the ultimate objective was carried out from a height of less than 800 feet. Owing to the lubricating system of one aero-motor suffering disablement from an unlucky shot the return journey had to be made on the one engine.

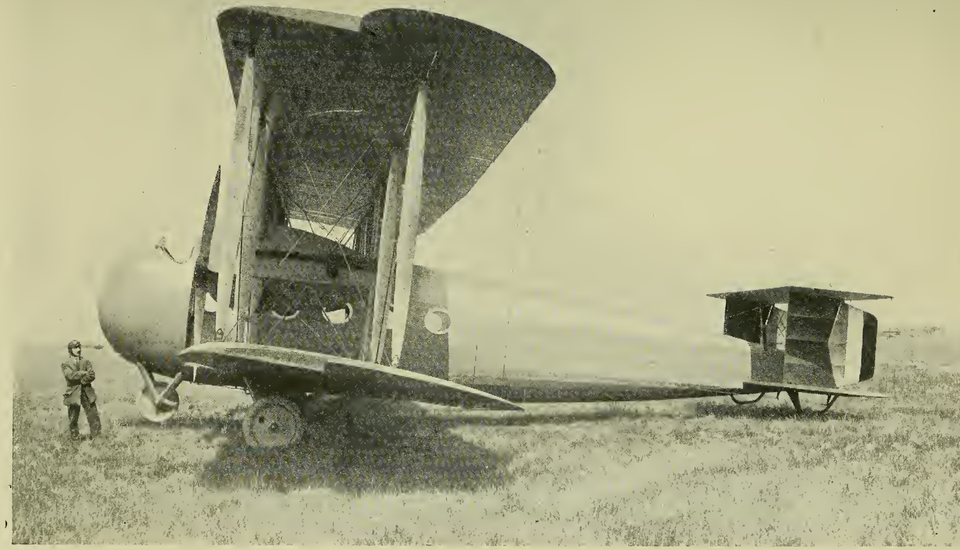
Since the cessation of hostilities this biplane has placed on record many achievements of equal impressiveness. It

was the first machine to fly to India, the journey in question being made from Cairo to Calcutta. In 1919 two vessels of the military type were stripped of their fighting impedimenta, and the fuselage converted into saloons, the two craft being christened respectively H.M. Air Liners *Great Britain* and *Silver Star*. These were provided for the conveyance, between London and Paris, of officials engaged upon the preparation of the Peace Treaty, and in one month carried 700 passengers without mishap. On April 19th, 1919, one of these machines, piloted by K. R. Parr and Captain Steward, with eight passengers aboard, set out from Andover to complete the aerial circuit of Great Britain. The route plotted was to Eastleigh and Dungeness upon the south coast, swinging northwards from the latter point to traverse the East coast, which was made by way of Clacton, Lowestoft, Waddington, Grimsby, Scarborough, South Shields. Crossing to the border the machine flew onwards through Turnhouse (Edinburgh) to Longside, Aberdeenshire. Here the nose of the machine was turned westwards to make Inverness. Proceeding from that point via Loch Ness, Lismore Island was picked up. After running due south as far as the Mull of Kintyre, the North Channel was flown, and from the Irish coast a bee-line was made for Belfast, thence south to Dublin. The Irish Sea was now crossed to pick up the Welsh Coast at Bardsey Island, cutting across Cardigan Bay to New Quay, on to Pembroke, thence across the Bristol Channel to Ilfracombe and Bodmin. Here an eastward course was set, the homeward run being made by way of Plymouth, Torquay and Bournemouth to Andover, which was regained on April 22nd. This, the first complete circuit of Great Britain, rivalling the achievement of Lieutenant Conneau "Beaumont," in 1911 for the circuit of Britain in connection with

the £10,000 prize offered by the *Daily Mail*, was made in 30 hours, the total distance covered being 1,599 miles.

The inauguration of civilian flying in this country was celebrated by the Handley-Page twin-engine biplane, with 11 passengers and pilot aboard, making a non-stop flight from London to Manchester—165 miles in 3 hours 40 minutes, while five days later this machine, with five passengers and a consignment of newspapers, flew from Manchester by way of Carlisle, Dundee and Aberdeen to Montrose, 315 miles non-stop in 4 hours 25 minutes. On May 6th another machine of this type, with four passengers, pilot and load, made a non-stop flight from London to Plymouth and back to Bristol, 310 miles in 5 hours 25 minutes. Another long non-stop flight was made four days later from London to Cardiff and back to Bristol, 250 miles in 3 hours 25 minutes. These merely represent the more notable flights accomplished by this machine during the opening twelve days of the month, several shorter trips, ranging up to 230 miles, being successfully accomplished. Altogether, within the first fortnight of civilian flying, twenty of these H-P machines made flights to all parts of the country, totalling 3,329 air-miles. Especially interesting was the non-stop night flight from London to Paris carried out by the authorities for military experiments, the occupants of the machine being in wireless telephonic communication with the coast throughout the journey.

The second commercial model is a large and more powerful type, known in the Service as the "Super-Handley" or "Berlin-bomber," having been designed and built especially for bombarding the German capital from the air. Although several of these machines were completed before the signing of the Armistice adverse weather conditions militated against



THE "VICKERS" PASSENGER-MAIL-FREIGHT AEROPLANE

The outstanding feature of this machine is the interchangeable body, enabling the aeroplane to be transformed from commercial to war service, or *vice versa*, within an hour or two. The car is built upon an entirely new principle

their being put to this duty. Consequently the citizens of Berlin have much for which to thank the weather during October, 1918. This biplane has a span of 126 feet from wing-tip to wing-tip, while it measures 64 feet in length, and has a height of 23 feet. In the empty condition it scales 14,000 lbs.—6¼ tons. It will carry 30 passengers comfortably, and 40 passengers if necessary, or cargo, and 3½ tons of petrol, its fully laden weight with load ready for the air being 28,000 lbs., or 12½ tons.

The aeromotor equipment comprises four 350 horse-power 12-cylinder Rolls-Royce "Eagle" engines, representing a total propelling effort of 1,400 horse-power. A single tank of 1,000 gallons of petrol is fitted, this being adequate to ensure a radius of action of 12 hours on the one charge. The petrol consumption ranges from 80 to 90 gallons per hour, while the maximum air speed is 100 miles an hour; cruising speed 90 miles an hour. The engines are disposed in pairs, in line parallel with the longitudinal axis of the machine, and flight can be maintained upon two aeromotors, though, of course, at reduced speed.

It was the Super-Handley which flew from Ipswich to India by way of Egypt, this flight including the negotiation of 800 miles of open Mediterranean Sea between Malta and Alexandria. Subsequently it made a non-stop flight of 1,000 miles from Cairo to Baghdad via Damascus. On this journey two single-seater aeroplanes were stowed aboard to be handed over to a squadron posted near Baghdad, which serves to indicate the freight-stowing capacity of this machine. It was a biplane of this type which, with 41 passengers, rose to a height of nearly 8,000 feet over London.

Like its smaller sister, this huge plane put up some striking flight achievements in this country since May 1st, 1919.

It signalled the opening of the British civilian flying era on that day by flying from Glasgow, with 2 pilots and 5 passengers, to Folkestone, a distance of 530 air-miles, in 6 hours 8 minutes, only one intermediate stop being made at Hendon. On May 13th this biplane made a flight from Belfast to Folkestone, 550 air-miles, with 5 passengers, in 6 hours 29 minutes, repeating the performance ten days later by covering 560 air-miles in 7 hours without a stop—an average speed of 80 miles an hour—with 6 passengers aboard. On this journey the pilot, while in mid-air, went into the engine-room, the machine thus flying uncontrolled for 4 minutes. During this self-same month Major Darley piloted one of these biplanes from Marston to Biarritz with 8 passengers aboard, the 600 miles being covered without a stop. Another striking flight carried out by a service pilot was that over England, the machine remaining in the air for 11½ hours without a descent, during which time it covered 836 miles. During the month of May the quadruple-engine Handley-Page biplanes made seven distinct flights, covering in all 4,016 miles. It was a vessel of this type which was entered for the Atlantic contest, the only alteration from the standard equipment being the fitting of an additional tank for 1,000 gallons of petrol, thus increasing the endurance to 24 hours. However, the weather proved antagonistic, and after continued delay the flight was abandoned.

The Handley-Page, especially the four-engined model, conveys a vivid sense of power, massiveness and strength. The under-carriage alone serves to emphasise this fact, being ponderous in design and construction, fitted with four large pneumatic-tyred wheels, which when inflated have an over-all diameter of about 4 feet. The cost of each of these wheels

is in the neighbourhood of £135, or a round £540 for the four. Nevertheless, despite the enormous span of the wings, the vessels can be stowed in relatively small hangars. As in the case of the Short seaplane, the wings are hinged, allowing them to be folded back against the fuselage upon landing preparatory to docking. In this way a very pronounced saving in space is obtained, the over-all width of the twin-engine class being 17 feet 6 inches and of the "Super-Handley" 46 feet—about one-half of the extended wing measurement. The Chinese authorities have extended their appreciation of this machine, numbers of the twin-engine model being under construction for the East during the middle of 1919, about which time the first completed machine was subjected to its final trials, in the course of which it carried 18 passengers at a height of 1,500 feet.

The Sopwith Aeroplanes

Among the fast machines designed for scouting duties in connection with the war, the Sopwith biplanes, notably the "Pup," achieved a well-deserved reputation. This type has been perpetuated to meet commercial conditions, though under the more pacific name of the "Dove." It is a modification of the war machine, and as a two-seater makes an attractive small sporting model. It is fitted with a rotary engine, the 80 horse-power Le Rhone, and the fuel tank is of adequate capacity to assure a three hours' continuous flight.

A little larger machine for high performance is the "Gnu" biplane, likewise fitted with a rotary engine, either a B.R.2 of 200 horse-power or Le Rhone of 110 horse-power being installed therein. The accommodation provided is for two passengers in addition to the pilot, the former being seated

behind the latter in a comfortably enclosed saloon, provided with safety-glass windows, while there is also space to receive 60 lbs. of hand baggage. This handy little machine is fitted with fuel capacity to permit a full-speed flight of 4 hours' duration.

The Sopwith large type commercial aeroplane is represented by the "Transport" model. It is a six-seater, four passengers being carried in the centre of the machine, while the fifth is accommodated in the pilot's cockpit behind the wings. If used as a freight carrier space is available for the stowage of 1,500 lbs. of cargo. The fuel-tank capacity is adequate to carry the machine, if passengers be aboard, through a non-stop flight of 6 hours, and of 8 hours if the machine be used as a cargo carrier.

This was the model with which Mr. Hawker sought to carry off the distinction of being the first man to fly across the Atlantic and, incidentally, to win the *Daily Mail* £10,000 prize for the feat. In the hope that he might be the first to reach Great Britain, he set out from Newfoundland on May 18th, 1919, two days after the American competitor, Lieutenant Commander Read, took to the air in his machine to make a bid for the honour by way of the Azores. Unfortunately, after covering 1,100 miles Mr. Hawker was forced to the water by a mechanical defect, to be picked up by a passing vessel, the damaged aeroplane being salvaged by another vessel and brought home.

CHAPTER XV

The Life-Belt of the Air

FOR many years past the parachute has been regarded merely as a vehicle wherewith to conduct a thrilling exploit in the air—a sideshow for the amusement of the crowds of a festival or fête. To have suggested that such a device could ever be converted into part and parcel of a flying machine in the interests of safety would have been to invite ridicule. However, accidents will happen, even to the best-built machines, and it is against the unexpected that full protective measures must be provided. One does not expect an ocean greyhound to founder after she has left port, but that contingency, extremely remote though it be, does not preclude the compulsory installation on board of a variety of devices—rafts, collapsible boats and life-belts—ready for the passengers and crew at a moment's notice in case of disaster.

It is somewhat significant to remark that the frequency of accidents, which were inevitable owing to lack of knowledge, during the infant days of dynamic flight, was responsible for the expression of brilliant thought in the devising of ingenious life-saving appliances for the air. Aviators were naturally keen to save themselves, if at all possible, from injury on the precept that the pioneer who survives a crash to-day will be able to fly another day. But there was a distinct aversion to utilising the conventional parachute for this purpose. This was not surprising seeing that the

apparatus is primitive, cumbrous and distinctly uncertain in its action, while, even should it work properly, there is a disconcerting initial period of inefficiency, permitting a fall of several hundred feet, before it comes into operation, and which is far from being reassuring even to the trained parachutist.

Accordingly the problem of parachute design was attacked from the very beginning once more by one of our leading civil engineers, Mr. E. R. Calthrop, M.Inst.C.E. He familiarised himself with all the deficiencies of the accepted apparatus, and then set to work to evolve one along totally different and novel lines. He has completely succeeded in his task. To-day there is no reason why an accident to an aeroplane or airship in the air, with perhaps the solitary exception of explosion which is instantaneously devastating and destructive, should be attended by the death of the pilot or passengers. The new parachute, "the life-belt of the air," can be adjusted within a few seconds, and the wearer can then leap into space with every confidence of being able to reach the ground in safety and without a perceptible shock or jar in landing, while descent is free from the slightest sensation. The wearer merely floats to earth.

As in all devices which work with unassailable perfection and efficiency, the airman's life-belt, or "Guardian Angel" parachute as it is generically called, is extremely simple both in its design, construction, method of operation, and casting off. The parachute itself is folded in a special manner within a small flat drum-shaped metal container. This vessel is made in two pieces, the upper and the lower part, the former forming the wind-shield, while the lower 24 inches or so in diameter is known as the launching disc. The parachute

itself is made of silk and so is light, extremely strong, and durable. It is packed within this container in such a manner that the slightest tug at the launching disc releases the whole, causing the parachute body to open out and to become distended, then to fall clear of the upper disc.

Extending from the bottom disc of the parachute is what is called the harness, terminating in what may be described as the life-belt proper. This comprises a simple and strong harness with holes through which the arms are thrust, and a waist-belt. The whole of the body can be supported within this simple apparatus, which in its general design is somewhat reminiscent of the chains of a gibbet, and it is so made as to enable it to be donned even if the pilot or passenger be placed in a somewhat awkward position, without effort within a few seconds, or it may be worn during the flight without inconvenience. This device is so designed and constructed as to relieve the wearer of all shock arising from the distention of the parachute and the consequent sudden arrest of fall due to the upward pressure of the air bearing upon the under side of the silk body, which becomes inflated as it were, and so imparts buoyancy to the whole. At the same time the wearer is prevented from giving a demonstration of the principles of the roasting-jack during descent, because he cannot possibly spin while coming down.

This parachute consequently represents a striking advance upon what has been used for so many decades by intrepid balloonists. The latter involves the use of coiled cordage, and, when the parachutist casts himself adrift in the air with this apparatus, there is a prolonged fall in the mass before the parachute commences to unfold to fulfil its designed function. If entanglement should ensue appreciable time

will elapse before it opens, the person falling with rapidly increasing velocity meanwhile, so that when at last the parachute does open, there is a distinct jolt or transmission of shock to the individual. At times the parachute has even been known to refuse to open, and the result in such a case is obvious—instant death to the daring parachutist. At all events, even under the most advantageous conditions, the apparatus will fall at least 100 feet before commencing to open, while free-falls of 200 to 500 feet or even more are by no means uncommon.

With the "Guardian Angel," however, there is no need to be apprehensive as to whether and when the parachute will open. Its design is of such a character as to ensure quick and positive action, no matter what the relative position of the man and the parachute may be at the moment of leaving the flying machine or what the speed of the latter may be. Obliquated tapes are used, issuing conewise from the container under a continuous tension. In this matter the wearer receives immediate support from the air. The nesting of the body of the device within the container assures the desired end being fulfilled without the slightest fear of mishap or entanglement, because the silk body emerges with a cylindrical column of air of the same diameter as the launching disc, over the edge of which it emerges, and the compression naturally opens the parachute forcibly to its fullest expansion practically instantaneously. The free-fall cannot possibly exceed the length of the shock-absorber sling, which is 13 feet 6 inches, because the moment this distance has been covered the parachute at once begins to open out, offering an effective support, which rapidly increases until the maximum degree of buoyancy has been attained by the distended silk body. Within 2½ seconds of leaving the flying machine

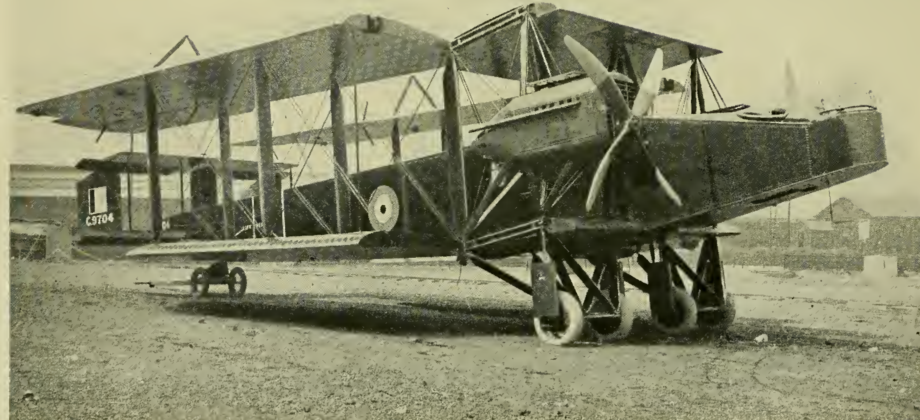
the individual is fully supported in the air, and the descent proceeds slowly, the individual finally alighting upon the ground at the speed of 15 feet per second, which is quite safe and imparting no more shock than would be encountered from a jump off a chair. The absence of high-speed diving, swinging and swaying completely removes all risk of nausea from the experience. As a matter of fact, descent in this manner has been described rather as a pleasant sensation.

Another point must not be overlooked. No skill whatever is required in making the descent, as is the case with the ordinary parachute. The apparatus is slung in its container from a suitable point, it only being necessary to see that it has a clear position. It can be attached to the underside of the aeroplane with the harness led into the machine and placed in an out-of-the-way position but within easy instant reach in case of emergency, and requires no more time to put on than is involved with a lifebelt. There is this one great advantage: it cannot be fitted wrongly or upside down. It will also be observed that the parachute can be employed to make a descent from a relatively low height—even 200 feet—whereas with the old-fashioned apparatus it is absolutely essential that a relatively high altitude should be attained so as to allow the parachute ample free-fall in case it should be slow in opening.

To ensure absolutely positive working it is only essential that the silk body shall be packed within its container in a certain manner. When this has been done by a duly skilled person the container is sealed, and the seals are broken only in the act of jumping out of the machine. The airman or passenger is relieved of all further action once the harness has been donned and fastened. It is only necessary to jump

clear of the machine without troubling about anything else, because all subsequent operations are carried out automatically. Another distinct feature of the invention is that should an accident befall any occupant of the machine necessitating skilled attention it is not necessary for the flying machine to make a landing. Communicating by the wireless with the aerodrome below, the airman can release the injured person while passing over the aerodrome confident in the knowledge that the injured or unconscious person will reach the ground safely and without incurring any further injury even upon landing, while the harness admits of easy release. It is also an eminently successful apparatus for dropping mail-bags, parcels and other objects from the air en route. Newspapers have been delivered in this manner, while the discharge of mails en route after the manner incidental to the travelling post office on our railways will probably be practised when the air becomes recognised as a safe medium for the conveyance of mail matter. In this instance it will be possible to introduce an automatic release system, similar to that which was employed for releasing bombs, and without reducing the speed of the flying machine in the slightest.

The circumstance that the aeroplane can be driven at full speed and release a passenger or load meanwhile is another outstanding characteristic. This was brought home very convincingly in the course of a demonstration. An aeroplane was travelling at 100 miles an hour air speed—130 miles an hour over the ground—at a height of less than 400 feet, when Major T. Orde Lees, A.F.C., R.A.F., who was aboard, made the jump with the parachute. This represented probably as severe a test as could be conceived, because the airman was naturally caught in the air-wash of the machine, which was travelling at the same speed as the aeroplane.



SOLVING THE AEROPLANE HOUSING PROBLEM

The Handley Page biplanes are provided with a device to allow the wings to be folded back. The over-all width of the two-engine machine ready for housing is thus reduced from 100 feet to 17½ feet.

This means that he was being drawn or sucked forward at a speed of 100 miles an hour, and, in fact, was dragging the parachute. But the latter instantly commenced its designed duty. It began to open, and as it did so in the air-stream naturally acted in the manner of a brake, so that a spirited tug-of-war ensued. The situation in the air was somewhat curious immediately the airman had drawn clear of the aeroplane. He was at a higher level than his parachute. The latter continued its work and became more and more extended. As it did so it acted as a drag upon the parachutist until at last the forward momentum imparted by the machine was completely lost, when the airman, in accordance with the law of gravity, gradually sank until he was under the parachute, which was now opened to its maximum diameter of 28 feet, exerting its utmost buoyant effort, and thus came slowly to the ground.

The fall of the parachute is somewhat interesting to follow. When first released obviously there is the tendency to travel forward at the speed of the moving body of which it formed an integral part, because it has become invested with the momentum of the machine. The man continues to be sucked along, though, of course, owing to the friction of the air, at rapidly diminishing speed. This braking action is accentuated by the fact that the parachute, being heeled over, offers a resistance to the air stream of the fast-moving flying machine. When at last the parachute is fully opened, for an instant it remains virtually stationary in the air, allowing the man to swing down to the vertical position like the bob of a plumb-line. Then follows a gradual vertical descent to the ground at the rate of 15 feet per second. As may be imagined the strain imposed upon the parts of the parachute and the sling carrying the falling person is enormous dur-

ing the first few seconds, but the individual is relieved of all such effects by the action of the shock-absorbing springs. The ability to withstand these enormous strains and stresses testifies to the beauty of the scientific design and strong construction of the apparatus.

The circumstance that the parachute cannot fail to act is its greatest asset. Distension of the body must take place from the enclosed cylindrical column of air which forces the body of the parachute to assume a flat bun shape through the air being compressed in the dome and the body as it were.

This lifebelt of the air is made in various types for certain specific applications, though the fundamental principle remains the same throughout. The modifications have been introduced for the purpose of enhancing the safety factor. Thus, in the case of fire upon an airship, it is imperative that one should get clear of the burning wreckage with the utmost celerity, and so the parachute is fitted with what is described as two speeds. The first ensures a high but constant speed first-fall to get clear of the vessel promptly and to a safe depth, when automatically the speed is changed into the established 15 feet per second descent. The depth at which the speed-change should be effected is carried out automatically, so that the user is quite ignorant of the circumstance and is not called upon to contribute to the action in any way whatever. Another distinct improvement is the incorporation of means to vary the descending speed or steepening of the gradient of fall, and to guide the parachute to a certain degree in a lateral direction, thereby enabling the parachutist to avoid an objectionable landing, such as upon trees, buildings or water. It may be mentioned that the special releasing device

incorporated enables the wearer to divest himself of the apparatus instantaneously which is of distinct advantage should the descent be made into water. Less than one second is required to secure complete detachment from the parachute, so that the user is free from all danger of becoming entangled in the apparatus after landing.

The Calthrop parachute represents the greatest contribution to auxiliary safety equipment for the flying machine yet devised. It is to the passenger through the air what the lifebelt is to the traveller on the ocean liner. Having conclusively established its positiveness of action and efficiency under all and every conceivable circumstances, its installation upon an aeroplane should be made as compulsory as is the provision of lifebelts upon a sea-going vessel. It occupies no appreciable space, while its weight is negligible, and the fact that it can be used with equal facility, irrespective of the position of the aeroplane, even if it be upside down, distinctly enhances its value. If this fact be realised we need hear no more of deaths from accident with the flying machine. Hitherto, public reluctance to travel by air has been due in no mean degree to the absence of any proved means of regaining *terra firma* safely in the event of misadventure while aloft. Now all the apprehensions are completely removed. Knowledge that there is a certain means of safe escape from aerial disaster cannot fail to exercise a wonderfully reassuring effect upon the public, one which would receive additional impetus from the compulsory equipment of the flying machine with such a device. The war has conclusively proved that it is absolutely reliable under all and any conditions. It will be recalled that upon the occasion of the arrival of R34 at Long Island, the first passenger to land was the officer who completed the last

1,000 feet between the airship and the ground by parachute, to supervise the subsequent mooring operations. Similarly, in connection with the projected trans-oceanic dirigible, of which a description is given in a subsequent chapter, a notable part of the auxiliary equipment is a complete installation of the Calthrop parachutes to meet the requirements of the passengers and crew.

CHAPTER XVI

The Flying Machine as a Mail Carrier

COMMERCE refuses to bow to any limitations imposed by the clock. It seeks to annihilate time and distance in the conduct of its affairs. The more intensive the system under which business can be conducted, the greater the volume handled, the more extensive the employment given, and the richer becomes the country embracing the beat-the-clock methods. As an instrument for quickening and widening business the aeroplane stands supreme. It can beat the clock, while it shrinks distance to negligible proportions.

Let us investigate this problem a little closer. A contract is being drawn up in London to the order of a Paris house. Under contemporary conditions, if it be desired to expedite matters, it is incumbent for the principal of one firm to reside in the city of the other during the operation—to be on the spot. But this is to the detriment of all other business of the house from which the principal is absent.

But consider what would happen if reliance were placed upon the post, even when working under normal conditions. The contract is posted in London on Monday afternoon, but it is not delivered in Paris until the Tuesday morning. It only requires the final signature which is immediately appended and the contract returned at once. But it does not reach London until the Wednesday morning. Two whole

days have been occupied in a simple operation, but one which is absolutely indispensable. Should a question crop up at the last moment, involving further correspondence, further delay arises, more especially if it involves dispatch of drawings or other documents, because the telephone cannot be impressed into service.

Now the aeroplane is available. The contract can be sent off by air on the Monday morning at 10 A.M. It reaches Paris at 12.30 P.M., the signature is affixed and the contract is returned by way of the air. The London house receives the document at 4.30 in the afternoon, and, that self-same night, instructions can be issued putting the working machinery in motion. The whole affair has been fixed up, signed, sealed, and put in hand within eight hours, and the principals of both houses, 250 miles apart, have been free to continue their ordinary business. Nothing has suffered the slightest interruption or delay. There has been a saving of at least 36 hours. Should an eleventh-hour difficulty crop up it is just as promptly settled by way of the air, and in this instance the saving of time becomes more pronounced.

The carriage of mails undoubtedly represents the most attractive field for the aeroplane—the sphere in which it is able to accomplish the most useful service, and incidentally to earn the biggest revenue. Commerce does not object to paying for special facilities, and there is no valid reason why a special express letter service should not be introduced, not only between the distant towns of these islands, but between our great commercial centres and the Continent. The charges might be five or six times what they are by the alternative means of conveyance, but there would not be the slightest objection to paying for this privilege upon the part of commerce. In official quarters there is a tendency

to delay such recognition of the speed potentialities of the aeroplane. Doubtless the feeling prevails that the way of the air fails to rise to just that degree of safety and certainty which has been attained by the railway and steamship. But commerce is prepared to run that risk. The air-mail could be kept quite distinct from the general mail; there would be no necessity to dispatch such by the air at incredible speed since the private letter writer does not object to a few hours more or less being occupied in the movement of his correspondence.

What can be accomplished in connection with an aerial mail service has been convincingly demonstrated to the world by the Government of Chile, which probably was the first authority to introduce a regular air-mail service. A number of Bristol monoplanes of exceptionally strong construction, having a speed of 130 miles an hour, although driven by an engine developing only 110 horse-power, were presented by the British to the Chilean Government some time ago. The Chilean airmen were speedily attracted to the qualities of this machine and its remarkable reliability and endurance. So much so that one intrepid airman, Lieutenant Cortinez, piloted one of these machines across the Andes and back, spanning the great Cordillera backbone at a height of nearly 20,000 feet, thereby establishing a new record in connection with trans-mountain-range flight.

The Chilean authorities, upon being convinced of the serviceability and reliability of the Bristol monoplane as demonstrated by the military pilots, promptly acquiesced in the suggestion for the establishment of an aerial mail service between the two great centres of population, Valparaiso and Santiago, to meet the desires of the financial, industrial and commercial circles in the two cities, the

inter-communicating railway service being far from sufficient. The direct distance between the two cities is 70 miles, but the railway follows a somewhat circuitous route of 115 miles. The journey between the two cities occupies three hours, this including a stop of about half an hour at Llay-Llay junction, while there are only two or three trains each way a day.

By Bristol monoplane the 70 miles between the two points is covered in 40 to 45 minutes, and this air-mail service is regularly maintained. The weather conditions which prevail in this part of the world are certainly exceptionally favourable to the maintenance of such a fast and efficient service—in fact they might almost be described as abnormally so. There is only one spell throughout the year—namely, during the months of June, July and August—when they may be said to be unfavourable. This is the time when the "Norther" prevails, but as this wind appears with the utmost regularity at about four o'clock in the afternoon it is an easy matter to arrange the service schedule in such a way as to eliminate the obstacle it might offer to the mail service so that the air-mail is maintained the whole year round. We are apt to look upon the Southern American countries as disposed to lag behind the rest of the world, and to be indifferent to the inexorable march of Father Time, but in regard to the acknowledgment of the aeroplane, and a British machine at that, as a mail carrier, the Government of Chile must be conceded as being strikingly enterprising, because in this respect it has led the rest of the world.

There are many attractive openings for an aerial mail service between the islands lying off the shores of Great Britain where the introduction of a regular postal service is urgently necessary to stimulate local development. And

what applies to Britain is equally applicable to many other parts of the world, where similar conditions obtain, and where opportunity to forge ahead and to develop business is held up by lack of postal facilities. In every instance an aeroplane could fulfil the requirement very efficiently and inexpensively.

The absence of this link of civilisation was experienced so much a few years ago among the inhabitants of Great Barrier Island lying in the Hauraki Gulf of North Island, New Zealand, as to induce an enterprising resident to establish a pigeon-post service between the island and the town of Auckland on the mainland, 60 miles distant. The service was not only keenly appreciated but enthusiastically supported, despite the franking charges being 6d. and 1s. per message. The latter, of course, were written on the extremely thin and light paper incidental to such operations, because the messages had to be attached to the bird's body. In this instance a fast machine would cover the intervening gap of water within about 30 minutes, and would be able to maintain communication on days when bird flight could not be safely attempted.

So far as the British Empire is concerned it is quite possible, indeed probable, that the air-mail will first find its official recognition with the inauguration of a service between Cairo and India. In the course of his presentation of the estimates for the air service to the House of Commons in 1919, Major-General Seely remarked that it is in Egypt, Mesopotamia and the Near East where air development has its greatest future. That is a territory of vast spaces and perfect climate, enabling things to be done by air which are quite beyond achievement by any other known means, except at prodigious expense. The possibilities of the airway between

Egypt and India were very emphatically brought home by General Salmond on the occasion of his notable flight in a twin-engine Handley-Page from the Egyptian capital to Calcutta via Karachi. At the same time he indicated that, as a mail route, this was of distinct strategical significance, and was one which might well be inaugurated.

But there are other parts of the Empire which present just as promising openings for the aeroplane as a mail carrier, such as the back blocks of Australia and the inner districts of the Dominion of Canada. Communities have become established in the wilderness, far removed from the generally accepted highways of communication. At the moment the mail service, while maintained, is a project of supreme difficulty, particularly in winter. These communities would welcome a rapid and frequent air service, and would willingly submit to the risk of their mail going astray occasionally in the knowledge that every effort was being made to render their isolated life more tolerable. These remote settlements, even to-day, have to submit to shortcomings which would never be tolerated for an instant in civilised districts.

Of course, in such territories as those of which I am writing, landing would present a certain degree of difficulty, while harbouring accommodation would be most primitive. But the people, in return for the increased facilities offered, would spare no effort among themselves to render the defects as negligible as possible. They would readily assist in the clearing and levelling of landing grounds and would promptly solve the hangar problem to the satisfaction of the pilots and themselves. It is the winter which would present the gravest obstacle to the aerial mail service, when the ground is covered with a thick mantle of snow. The

prevailing white pall might mislead the airmen, but it would not be an insuperable obstacle to indicate the landing ground in a sufficiently distinct manner. Furthermore, under winter conditions the waterways would be brought within possible use as landing grounds, and would be worthy of consideration from the level surface they then present. A wheeled undercarriage would be impracticable, but there is no valid reason why the aeroplane should not be equipped with toboggan skids.

The severe winter conditions would preclude the use of an aeroplane made of wood. A machine wrought of metal throughout, such as the "All-metal Bristol," would need to be employed, and alone would be found capable of withstanding the rigour of the climate, as well as the hard wear and tear to which it would be subjected. The snowstorm would be the gravest danger. Not only would it be as impenetrable as a fog off the Grand Banks, blotting out land and sky, but it would tend to settle on the planes, in which event the superimposed weight which it represented might become an adverse factor, and act as a drag upon the engine, even if it did not imperil the safety of the whole. These are questions for thorough investigation and should not prove beyond solution. The inauguration of such a mail-carrying system would be hailed with wild enthusiasm, inasmuch as many of these remote and northern villages have to wait for weeks for their mails.

Alaska and the Pacific seaboard north of Prince Rupert offer prodigious scope for aeroplane development, although in this particular instance its aquatic colleague, the seaplane, would probably prove the most suitable aerial vehicle for such a service. Scattered along this seaboard, skirting what is colloquially known as the most silent sea in the world,

where there are no steamship lanes and very little passing marine traffic, are innumerable communities engaged in fishery, mining, lumbering and other enterprises. But the coast is as freely indented as that of Norway, offering excellent refuge for seaplane-carriers. In this instance mail carrying might readily be combined with some other service, such as general patrol, even if the craft did not actually become "Planes of all trades," taking the place of the few patrol boats employed in the service, and extending a hand for a thousand and one purposes, from the conveyance of missionaries, officials, traders, business-men, parcels, produce, and what not within the limits of their capacity. Alaska is a vast country, but it seems to be much bigger than it really is, owing to the infrequency of its steamship connections and the few slow-moving craft trading in the waters washing its shores. With the introduction of large speedy seaplanes its size would shrink because the scattered communities would be more closely linked together. Instead of being days or even weeks apart, they would be within a few hours' reach of one another, and the feeling of isolation which at present prevails would be very pronouncedly dispelled, while by the maintenance of frequent connection with the ports farther south—Vancouver, San Francisco, Portland, Tacoma, Seattle, Victoria—by ocean-going seaplanes or flying boats, the thousand miles of sea would not feel like ten thousand leagues of salt water as is the case at present. In such territories as these the seaplane, ostensibly a mail carrier, but willing to lend a conveying hand to anything and everything within its capacity, would represent the biggest boon ever bestowed upon hardy colonies of indefatigable trade builders.

The American Government, in its realisation of the postal

THE "BERLIN BOMBER" OR "SUPER-HANDLEY" IN COMMERCIAL GUISE

This four-engine Handley Page biplane weighs 14,000 lbs. empty, and 13 tons loaded. It has a span of 126 feet. accommodates 30 passengers, and is driven by four Rolls Royce aeromotors, each developing 350 horse-power.

possibilities of the aeroplane, is developing air-mail routes with true American enterprise. At present these services are supplementary in character, duplicating as it were the other means of communication between the leading cities in the busiest corners of the country. Thus we have air-mail routes between New York, Philadelphia and Washington; New York and Chicago; and so on. But the maintenance of these air-routes is proving invaluable. Operation is yielding experience which it would be well-nigh impossible to obtain in any other way. Speculation and estimates are giving way to certainty and definite charges, and the tendency is downwards. Thus, when the first air-mail in the United States was inaugurated, the charge per letter was 24 cents—one shilling. But the service proved so popular that it was found possible to reduce the charge to 16 cents—eightpence—and more recently to 6 cents—threepence.

Germany has established an air-post system between Berlin, Leipzig and Weimar; Berlin and Hamburg; Berlin, Frankfort, the Rhineland and Westphalia; and Berlin and Warnemunde. The last-named route is somewhat important, being part of a scheme for accelerated postal communication between Germany and the Scandinavian countries. It is well known that both Norway and Sweden are developing aeroplane services upon a somewhat imposing scale, essentially for linking up the various towns and cities to facilitate commerce and business, and so it is also anticipated that a seaplane link will be introduced between Warnemunde and the Swedish coast in connection with through express air-mail services between the two countries. In so far as Germany is concerned the aerial mail service has been introduced as a substitute to the railways, which have fallen into a sorry condition as a result of the war. The probability

is that, upon the restoration of the railways, the aerial post will sink into insignificance, being reserved for highly-privileged special delivery service.

Aerial postal developments, however, are not likely to develop very markedly until the precise character of international commercial flying is established. So many points, which have never arisen before in negotiations of this character, will have to be decided. Rates will have to be settled, and upon this one point alone there is considerable divergence of opinion. Possibly a zonal system will be introduced with all its concomitant flaws and difficulties, unless an international clearing-house is established or the respective governments assume the responsibility of the aerial service within their borders. For instance, it is suggested in one quarter that the charge for aeroplane letters between London and Paris should be one shilling per letter of one ounce, while another section of the commercial community maintains that sixpence would be an equitable fee. The question of charge, however, will probably depend upon the actual cost of maintaining the service. It is scarcely likely that the European Governments, faced as they are with heavy National bills due to the war, will be disposed to assume additional liabilities in the form of subventions. The difficulty could be solved by handing over the international aerial mail service to private enterprise, leaving the latter a free hand to establish the charge based upon the actual expenditure and cost of maintaining the service, and paying each Government a royalty according to volume of mail handled, as compensation for business diverted from the various official systems. Such a policy would stimulate the utilisation of those machines most eminently adapted to the work, instead of official recognition by favour which other-

wise would probably obtain, irrespective of efficiency and merit.

If aerial mail service be popularised and encouraged by the levy of low charges, on the principle equivalent to mass production in manufacture, we should find the tendency towards heavy fast mail-carrying aeroplanes develop, and this, in turn, would exercise a beneficial influence upon the evolution of the small-parcels express carrier which is every whit as vital to business as the accelerated letter post, since it would allow the swift transmission of samples. For instance, assuming the weight of the aerial mail letter at one ounce, a Handley-Page four-engine machine would be able to carry 170,000 letters, while a "Bristol Pullman" would be able to handle 64,000 letters per journey and at a speed of 100 miles an hour. But the probability is that appreciable time would elapse before sufficient traffic would be forthcoming to permit the profitable employment of such machines, which undoubtedly are the most efficient aeroplanes in Europe for such duty to-day.

The development of the aerial mail, although it is admittedly slow and somewhat spasmodic, is bringing joy to one class of the community—the philatelist. He is being given the opportunity to proceed hunting vigorously in a new field. Various countries have already introduced air-mail postage stamps, notably the United States of America, Canada, Newfoundland, Switzerland, Belgium, Austria, Germany, Hungary and Italy. Doubtless many are naught but freaks of the designer's art, but sufficient interest and enthusiasm have been aroused to create a market in these varieties. Up to the present the sum of £4,000 probably represents the top price yet paid for an air-mail postage stamp. This was for a whole sheet of "error" of the 24-cent

United States air-post stamp—the first to be issued. By some means or other the vignette of the biplane, the characteristic feature of the stamp, was inverted. Countries of Europe impoverished by war might do worse than emulate the practice of certain American States—ring the changes upon their air-post stamp issues. The sale thereof would constitute at least one source of revenue. The air-stamp fever would appear to offer immense possibilities in this direction.

CHAPTER XVII

Aerial Photography—The New Pastime

WE are all photographers now. The perfection of the "you-press-the-button-and-we-will-do-the-rest" system of taking sun-pictures has attained such an extensive vogue as to render the compact, light-weight, inexpensive pocket-camera an inseparable companion upon one's wanderings. Having snapped all sorts and conditions of pictures upon land and water from the conventional—and often unconventional—standpoint, the enthusiastic amateur is sighing for fresh worlds to conquer. The ability to travel through the air obviously provides him with just the opportunity for which he is seeking. It is only natural to anticipate a craze for recording pictures of this mundane sphere as the bird sees it, aspirations in this direction having been stimulated by the magnificent array of pictures presented at the exhibition of aerial photographs taken by the Royal Air Force, which, it must be conceded, were truly wonderful.

In these circumstances we may safely expect the passenger to regard his pocket-camera as even more than usually indispensable when setting out upon the aerial journey. Once the sensation of flight has worn off the camera will be snapped with more than usual vigour to secure vistas of the ever-changing panorama below. It seems so "dead easy," but it is to be feared that many miles of films and scores of plates are certain to be exposed to no account. The

enthusiast will encounter many disappointments and will be disposed to wonder why his little friend, so trustworthy on the ground beneath, can be so fickle up aloft, even if he does not go so far as to invest the work accomplished by our fighting bird-men with trickery.

It is not so ridiculously easy to photograph from a few thousand feet up as upon the ground, at least with the conventional appliances, as it may seem for many reasons which cannot readily be realised. Aerial photography is a branch of the craft apart; the conditions are so vastly dissimilar. The work is conducted from quite a different angle and is affected by matters pertaining to light, atmosphere and other circumstances which are never encountered upon *terra firma*. Finally, lines of perspective seem to develop uncanny and inexplicable freakish kinks and twists, rivers and roads appearing to run uphill, mountains to vanish, depressions to level out, and houses and lofty buildings to assume a common *vraisemblance*.

To grasp why this should be so it is necessary first to realise the viewpoint offered from the aeroplane or airship. The camera is really poised in a gigantic basin, because the horizon naturally rises as the level of the eye is elevated. If one take a pudding basin and stretch two strings at right angles across the top in such a way as to cross one another at the dead centre of the circle described by the rim of the basin, the point of bisection will represent the aeroplane and camera in relation to the earth beneath, the walls and bottom of the vessel corresponding to the ground. Thus it will be seen that one is really called upon to photograph a huge concavity.

So far so good; but the earth is a sphere, and so its surface is really falling away in perfect spherical contour, from

the point immediately beneath the camera towards the horizon. Accordingly, the position is somewhat paradoxical. There is a concavity arising from the elevation of the eye and of the horizon in opposition to the natural convex curvature of the earth. The latter is really more pronounced than it may seem. If the distance from the elevated camera to the horizon be 20 miles the actual curvature of the earth in that distance is about 21 feet. The conflict of these two antagonistic forces is capable of playing many strange pranks, especially when oblique photography is practised, that is to say, when the camera is not pointed vertically downwards, but at an angle inclined towards the horizontal, giving expression to disconcerting distortion.

The illusion is decidedly quaint. Looking directly downwards the earth appears to be as flat as the proverbial pancake, especially if the sun be in the zenith or be not shining upon the earth at all, owing to obstruction by clouds. A gigantic iron appears to have been passed over the earth's surface, rolling out the protuberances or hills and removing the dents or valleys. A lofty cathedral spire, so imposing from *terra firma,* when viewed vertically has no more height than the ramshackle chicken-run in the backyard close by. Towering trees look like scrub. The prevailing flatness is particularly striking owing to the absence of shadows. When the sun's rays come from a point well down upon the horizon, casting long shadows, as one becomes familiar with the unusual picture one can commence to unravel the eminences and the deep depressions, as well as the buildings. Shadows impart a sense of height to the objects upon the earth's surface. Under dull diffused lighting conditions a photograph of rolling country is certain to be disappointing, especially when taken with the popular type of camera and

developed in the conventional manner. A bird's-eye view of undulating, well-wooded Kent, or even of the rugged mountains of Wales, appears to be as void of character and relief as the flat Sahara or the expansive American plains.

Then the atmosphere plays its own peculiar pranks. It will upset all calculations and carefully preconceived ideas very dramatically. Upon an ideal summer day, when the air appears to be as clear as crystal, a thin bluish haze will appear to be hanging over the earth. The eye observes it but suffers no inconvenience since the organ is wonderfully constructed and able to accommodate itself to natural conditions. It is disconcerting to the photographic lens and sensitised plate; may be so pronounced as to render it impossible to secure a picture of the panorama unfolded below unless adequate corrective measures have been incorporated.

From this it will be seen that the chances of being able to obtain clear-cut, well-defined pictures of a bird's-eye character with the popular camera are doubtful. This is not to say that pictures are impossible with the usual photographic recording companion, because I have seen excellent pictures taken with a thirty-seven-and-sixpenny vest-pocket camera from a height of 1,000 feet. But they are the exceptions which prove the rule, and were taken under conditions which very rarely prevail.

Consequently, if the aerial amateur enthusiast would aspire to success in this unusual field, unless he is quite content to waste films and plates by resort to hit-or-miss tactics, he will equip himself for the task with the special facilities which prolonged scientific thought and experience have evolved. They are a direct product of the war and serve to prove that in one respect war, while to be deplored, is yet able to be constructive, because otherwise it is doubtful

whether any incentive to prosecute experiment and special investigation in this highly specialised field would have been offered.

The difficulties which have to be overcome to assure success in aerial photography are many, apart from those which may be said to be of a natural character, such as atmosphere. This is particularly the case with the aeroplane. The heavier-than-air machine is always "alive"; it is like the rowing-boat lolling upon the water. No matter whether the sea be as smooth and as still as the sheet of glass the rowing-boat will be observed to have a slight movement. The aeroplane, no matter how steadily its course may be maintained nor how skilful the pilot, is always quivering. It may be a movement due to the air or to vibration set up by the engines. Then again one must not forget that it is travelling at relatively high speed, whether against or down wind. The range in independent speed even is very wide. It may be only 50 or so miles an hour; on the other hand, it may run up as high as 100 and 120 miles an hour.

The fulfilment of these two conditions will render obvious the necessity to be equipped with a camera designed along special lines—lines adapted to operation in the air. And it is the evolution of the aerial camera which represents such a distinct achievement in British scientific circles, because at the moment the British camera is far and away the best instrument which has yet been devised for this class of work. One firm has made it a special study, which, bearing in mind its resources and past experience, spread over many years and embracing every conceivable photographic field, is not surprising. The firm in question is the Thornton-Pickard Manufacturing Company, Limited, of Altrincham, of shutter fame, and the details narrated in connection with this

essential part of the equipment with which I deal refer exclusively to their apparatus, with which the wonderful photographs standing to the credit of the Royal Air Force were made. I emphasise this fact to reassure the aspiring enthusiast that there really is no deception, and that the pictures in question are the product of direct photography, free from all chicanery.

The general features of the cameras which have established their extremely favourable value in aerial photography may be gathered from a reference to the plate opposite page 310. Three specific types have been evolved, inasmuch as experience has sufficed to prove that as yet no one camera can be designed for universal use, that is if the highest attainable results are sought. As already mentioned, two broad classes of pictures may be taken from aloft. The one is the oblique picture, in which the camera is aimed at the object at an angle to the horizontal; the other is the dead vertical or "plan" picture, where the longitudinal axis of the lens is at right angles to the horizontal plane of the earth.

Of the two broad classes, it is probably the first-named which will be most popularly favoured, as it is free from that absolute dead flatness characteristic of the plumb-line photograph. The first-named is particularly adaptable to the taking of photographs of objects and points of interest from an unusual point, and is the type of picture which will most readily appeal to the amateur. The last-named is more useful for the preparation of survey and other scientific pictures. Of course such pictorial records are sure to be made to a lesser degree by the amateur, although with ultimate reluctance owing to their generally monotonous character.

Accordingly, before setting out upon the aerial trip the amateur should make up his mind the class of picture he

desires to secure. If the oblique picture be his direct and general desire, then he should provide himself with the "A" type, which may be described as the best adapted for the varying fancies of the user. Although essentially designed for recording oblique pictures it may be utilised for vertical photography, and will be successful within certain limits when the amateur has become thoroughly conversant with the peculiar conditions obtaining in this field.

This camera can be held in the hand and be operated in the usual manner. It is of simple construction and fool-proof in its operation. It represents the first type used for military purposes, and for its particular class of work, especially snap-shotting of objects and points of interest, has not been superseded. Fundamentally it follows accepted or familiar lines. It is fitted with a specially designed focal-plane shutter having an adjustable aperture, while an ingenious device is also incorporated to prevent exposure being made inadvertently. In other words, the operator must perform a definite conscious action to take his picture. With this camera a Mackenzie-Wishart slide is used. This camera will make wide appeal owing to its relatively light weight and inexpensiveness. Complete, it weighs from five to six pounds, while, fitted with a suitably designed aerial F/4.5 lens, its cost is about £20, thus bringing it within reach of the largest class of amateurs.

One feature incidental to the use of all hand cameras is equally applicable to this instrument. It must be held rigidly, or preferably should be fixed rigidly to the fuselage of the aeroplane. The natural "liveliness" of the machine and vibration arising from the running of the engine may provoke qualms as to the advisability of attaching the camera to the machine to form part and parcel of the whole, but

experience has demonstrated conclusively that such movement does not communicate any visible blur to the resultant picture even upon enlargement. On the other hand, if the camera be held, the "liveliness" of the machine is likely to be accentuated by the innate inadvertent movement of the operator, and the sum of the two movements is likely to be revealed very disconcertingly in the resultant record. Accordingly, the operator is strongly advised, no matter how skilled he may be in the manipulation of a hand camera, to attach the instrument rigidly to the machine.

Of course, circumstances may render it impossible to fix the camera in this manner. If such be the case and sole dependence upon the hand be imposed the operator must be extremely careful not to give the slightest pivotal movement to the camera at the instant of exposure. If this precaution be not observed the whole image will be blurred. It is this pivotal movement, so extremely difficult to prevent, which is so fatal to aerial photography. On the other hand, communication of the aeroplane's inherent vibration to the camera exercises no ill effects.

The "C" type aero camera represents what might legitimately be described as the application of photography to the flying machine in the scientific sense. It is designed essentially for taking directly vertical photographs and in rapid succession, as may be required for the preparation of a continuous or coherent photographic record for the elaboration of a detailed survey. It is normally fitted to the machine in such a manner as to allow the lens to project through the base of the fuselage to ensure direct plumb-line direction. It is of the plate-changer or magazine type, 18 plates, carried in sheaths, being placed in a magazine provided at the top of the camera. So far as operation is

COMFORT IN THE AIR

The saloon of H.M. Air Liner "Silver Star," showing arrangement of the cabin. The sister Handley Page aeroplane "Great Britain" was similarly equipped. The roominess and comfort provided may be gathered from this illustration.

concerned it would be difficult to conceive anything simpler, or a means for taking pictures in more rapid succession, this last named factor being mainly dependent upon the skill and dexterity of the operator.

All that is required is to move the knob to and fro. The plate, after being exposed, is transferred to another magazine exactly like that mounted upon the top of the camera, while, during this plate-changing task, the shutter is automatically set for the next exposure. When the supply of plates has been exhausted the second magazine has naturally become fully charged. The full magazine is withdrawn, the empty one from the top is placed underneath to act in turn as the receiver, while another charged magazine is inserted at the top. The latter, upon being emptied, is always transferred to the bottom, the practise thus being somewhat similar to the progressive movement of the spools in a cinematograph camera. This instrument is of robust design to withstand the rigors of hard wear and rough usage, while its mechanism is extremely simple and fool-proof, it being quite impossible to derange it by normal operation.

In setting up this type of camera care has to be observed not to allow the instrument to project too pronouncedly through the floor of the fuselage, otherwise the lens contributing to the resistance offered to the air will exercise an appreciable drag upon the machine. One might naturally ask why it should not be attached to the side of the fuselage. This may be done, and in fact is recommended with the "A" type, but there is an objection to this practise in the case of the "C" model. The field of view is likely to be curtailed by the side of the fuselage, whereas by pointing it through the floor a clean sweep of the earth is obtained. The camera being a fixture and being set dead, vertical oblique

pictures can only be taken by banking the machine, a simple task for the aviator, but, as will be recognised, entailing communication between the two men, the pilot manœuvring the machine to coincide with the photographer's desires.

Now, there are occasions when it will either be impossible or superfluous to send an independent photographer aloft. To facilitate the taking of photographs by the pilot the third or "E" type of aero camera has been evolved, and it may be said to represent the latest and most beautiful expression of ingenuity in this privileged realm. The compactness of the machine is obvious; it can be stowed within a small case when not in use. As in the case of the "C" camera it is designed essentially for taking vertical pictures, and to this end is mounted so as to point through the floor of the fuselage. It is also of the plate-changer or magazine type, being entirely automatic in its action. Its outstanding feature is alternative distant control. There are two cords, which may be of any desired length and which may be led by suitable arrangement to the pilot's seat, or should an independent photographer be carried they may be led to his position. These cords are alternately pulled, both movements making the exposure, changing the plate and resetting the shutter. An alternative release is fitted, this being in the form of a length of Bowden wire fitted to a convenient pistol mounting. In this instance the operator has merely to press the trigger to make the exposure. This instrument, in common with its contemporaries, has a fool-proof simple mechanism with adequate precautions against accidental exposure, while the magazine-changing system follows the lines incidental to the "C" type aero camera. Here again, being set for vertical photography, the machine must be banked to take oblique pictures, but in the one-man machine

this is a simple matter, the control of the aeroplane and of the camera being under the sole control of the pilot.

Experience has established one factor. This is, the advisability to fashion aero cameras of metal. This not only ensures great strength combined with light weight and more robust compact construction, but militates against the tendency upon the part of the camera to suffer derangement or to become stiff in working under weather conditions. It has been learned that the atmospheric changes, which are considerable and wide in the air, are decidedly detrimental to the use of wood in the construction of these instruments. The "E" type is built of metal throughout, and there is every reason to believe that all instruments designed for aerial duty will be contrived from metal instead of wood in the future.

Of course the two automatic cameras designed for vertical work are more costly than the instrument designed for hand use. The figure may be said to range to £50 or more, this factor being dependent upon the lens. Moreover, they are more weighty, as may be expected, the plates themselves, as any amateur will readily recognise, contributing to this feature in no slight degree. But when employed for scientific work these two factors have little, if any, significance, so long as the results fulfil requirements concerning definition and clearness of view, coupled with the ability to tolerate pronounced enlargement.

While aerial photography has specific coincident difficulties it also possesses many pronounced simplifications, that is when compared with work upon the ground. The operator is relieved of all necessity to trouble about focussing. The lens is always set at its infinite focus, which, however, it may be mentioned, is considerable, and which in turn

necessitates the camera being of unfamiliar long dimensions. For instance, to take a clear detailed picture from a height of 16,000 to 18,000 feet it is necessary to have a camera exceeding three feet in length. As in the case of the familiar instruments, finders are fitted, but they are really only serviceable as centring devices. It is not practicable to supply a finder which will reproduce the exact picture as taken by the camera because the area covered by the lens at the altitude at which an aeroplane generally flies is very great, notwithstanding the fact that the lens has a relatively narrow angle. Consequently, in taking the picture, the operator must aim at bringing his main object to bear upon the bisection of the spider lines of his finder.

Sharpness of picture and clarity of definition depend to a very vital degree upon the shutter and its adjustment, both in regard to width of aperture in the blind and its speed. Contrary to popular opinion, perhaps, the exposure is longer than what might be expected, bearing in mind the speed at which the machine is moving. Upon the ground an exposure of one-thousandth of a seccnd is by no means uncommon, but then the camera is relatively near the object. As the distance between the camera and the object increases it is possible to slow down the shutter speed very perceptibly and yet secure a picture free from blur.

In order to obtain the most satisfactory results in aerial photography it is preferable not to use too high a shutter speed, and to use a slit ranging from 1 to 1½ inch in the blind. A focal-plane shutter is imperative, and in view of the fact that the Thornton-Pickard Company pioneered this form of shutter, and naturally has amassed wide and peculiar experience concerning its design and use, it is not surprising that the British aero cameras fitted therewith have yielded

such uniformly excellent results. The between-lens shutter, with which the majority of small cameras are fitted, and with which the amateur is obviously most familiar, is to be discouraged in this work. Its efficiency is so low, while, moreover, it is impossible to obtain sufficient speed on any between-lens shutter large enough to take an 8- or 10-inch F/4.5 lens.

At F/4.5 the exposure ranges from 1/100 to 1/150 second according to light conditions. If it be a brilliant day the latter exposure will be adequate, the width of the slit in the focal shutter blind being 1 inch, but if it be dull the blind slit width should be increased to 1½ inches, and the exposure reduced to 1/100th second. The height at which the flight is made exercises a distinct influence upon this factor, as well as the condition of the atmosphere. Doubtless, under commercial conditions, the height of flight will lie between 1,000 and 3,000 feet, but here again natural conditions play a prominent part. However, whatever shutter speed be selected, one vital point should be borne in mind in setting the focal-plane shutter: there should be a fair tension upon the blind, allowing it to run fast, but free from that peculiar jump which is sometimes experienced in a shutter of this character when the tension spring is wound to its extreme limit. Fortunately the risk of jar and subsequent blurring of the image from this cause is pronouncedly reduced in the Thornton-Pickard focal-plane shutter, owing to its wide latitude and perfection in design and excellence of construction.

As a special camera is essential for those who would excel in this unconventional field of picture-making, so must a distinctive type of lens be employed. The most beautifully built instrument, of the smoothest working character, simplicity

of operation and fool-proofness, counts for nought if the lens be indifferent. To have suggested before the Great War that British lenses could be used for this work would have been construed as rank photographic heresy, the Germans being held as super-masters in the science of photographic optics. The war changed opinions on that matter, although it was a somewhat slow, tedious, and more or less painful operation, the authorities even having been inoculated with lingering traces of this poisonous virus up to as late as the closing days of 1917. The Zeiss-Tessar lens was upheld by the Germans as the finest expression of science and manufacture in this realm, and was declared to be the model for the whole world. The British, in their folly, took the Germans at their own valuation, instead of satisfying themselves upon this point. Experience in the world of aero-photography has proved this to be one of the biggest bluffs foisted upon a meek and unsuspecting British public. One need only compare the German aerial photographs with those taken by British fliers to be satisfied upon this point; while, should one be still unconvinced, and yet be conversant with the means of testing lenses to determine their essential values, one should dive into the laboratory and embark upon careful trials. Even the most perfunctory tests will suffice to prove that here Britain has left the rival revelling in his own conceit and miles behind.

Considering the apathy with which British photographic optical effort was regarded five years ago, it is wonderful to be able to record such strides as have been made, which again suffices to prove that there is nothing to fear when given a fair field and no favour. The slur cast upon British prowess in regard to lens-making was also inadvertently extended to the glass manufacturers, a woeful ignorance prevailing in this

country of the circumstance that England possesses one of the leading optical glass-makers in the world—one which even the Germans, with all their dubious methods of trading, could not supplant. The Chance family of Birmingham, who have supplied more glass for the fabrication of the wonderful lenses used in lighthouse engineering than any other competitor in the world, have probably forgotten more about the peculiar craft than ever the Germans learned, and what they can do when the craft is swung round to photography—well, the photographs taken by the Royal Air Force offer sufficient testimony.

Fortunately for the country at large there were several firms available to design and manufacture the special lenses required for the aviation cameras; namely Taylor, Taylor & Hobson, the well-known Leicester makers of the famous Cooke lens, which is a by-word to every amateur enthusiast; Dallmeyer, the record of which in regard to lenses is one of the best sustained; Ross, whose product is as well known as the Cooke; and Aldis Brothers. All these firms devoted their energies to the perfection of special lenses adapted to aerial photography, and there was not one which did not excel the achievements of Goerz and the other members of the German ring, albeit the work was entirely new, and never was attacked before the war burst upon us.

The lens intended for aero-photography differs in many respects from its contemporary used with the pocket camera and its many variations upon the ground. They are of long focal length, the smallest ranging from 8 to 10 inches. As we are all photographers in these days, there is no need for me to dilate upon any explanation of focal length. This focal length was used when flying was possible at relatively low altitudes—one which will conform with civilian flying, and

for this reason will probably represent the type in most extensive demand.

In the early days, in order to secure all advantages of speed, the lens of F/3.5 aperture was favoured; but practise proved it to be too big for aerial work, a disadvantage which will obtain just as strikingly under peace as under war conditions. It was discovered that, all things considered, the F/4.5 lens gave the most satisfactory all-round results, and this aperture will doubtless become standardised for civilian aero-photography. Thus we may put the lens down at 8 to 10 inches F/4.5. It should be racked out to the infinity focus and be definitely locked in that position. Stopping down is unnecessary, inasmuch as the British lenses give a wonderfully clear and sharply-defined image right up to the edge of the plate, and this virtue again facilitates the task, because it enables the lens to be used at full aperture, most of the official lenses, indeed, being made with a fixed F/4.5 aperture.

As flying height is increased, it is necessary to use a lens of longer focal length, though the aperture be maintained, although upon this last-named point there has been a certain revision of opinion. So far as the war was concerned it was the strength possessed by the hostile fixed anti-aircraft batteries and the accuracy of their fire which compelled us to penetrate the highest regions of the air, and in regard to their anti-aircraft defences the enemy proved to be uncannily progressive. It was for this reason that the photographs which were taken of Zeebrugge Harbour had to be taken from the extreme altitude of 16,000-18,000 feet, which, however, by no means represented the limits of our photographic ability, since many magnificent pictures were taken from 19,000 feet, and, to the lay-mind, knowing nothing of the

H.M. AIR-LINER "GREAT BRITAIN"

This vessel and her sister ship "Silver Star," twin-engine Handley Page aeroplanes, were fitted with comfortable saloons expressly for the conveyance between London and Paris of officials engaged in the preparation of the Peace Treaty. In one month the two aeroplanes carried 700 passengers

difficulties encountered, might have been taken from 1,000 feet, so clear and detailed are they.

Even this did not represent finality in regard to our endeavours, because, but for the cessation of hostilities, advances in anti-aircraft artillery would probably have forced our flying photographers to such incredible altitudes as 26,000 or even 30,000 feet—five to six miles—which, in turn, would have imposed additional demands upon our optical science leaders. As it was, the demand to extend such respect to the German gunners stationed at Zeebrugge was responsible for the largest and finest aero lens yet designed and made. It is the creation of the Aldis Brothers of Birmingham, whose achievements in photographic lens production constitute such an outstanding feature of contemporary manufacturing effort and ingenuity in these islands. The lens in question has a focal length of no less than 36 inches, while it is of F/6 aperture, and measures 9 inches in diameter across the front face.

This is generally regarded as the crowning achievement in aero-photographic lens design and production, and is ungrudgingly admitted by the authorities to be far superior to the best which German makers have yet been able to produce. In comparison with this huge lens the popular Aldis ¼-plate F/4.5 lens is indeed a pigmy. Even its immediate predecessor, the 20-inch F/5.6 aero lens was a giant in comparison with its familiar baby consort. Mounted in its flange the 36-inch lens weighs 16¾ lbs., the weight of the lenses alone—the shaped and polished glasses constituting the set—being 7 lbs.

It may be urged that such lenses as these are abnormal; that while they were absolutely indispensable to war, they will be useless for commerce. But is this so? Of a truth

they will not be required by the amateur—their price alone will tend to render them prohibitive to him; but aerial photography is destined to take many a new turn. One of the most promising fields for the aeroplane under civilian conditions is for the survey of new countries and the conduct of explorations of little-known parts of the earth from the air. While it will be possible to conduct much of such work from relatively low altitudes—5,000 to 8,000 feet—other areas will demand flight to far greater heights than have ever been recorded in connection with military operations. Our knowledge of the mighty Himalayas is scanty and dubious. The source of the Bramaputra still remains to be discovered. What do we know about Mount Everest and its environs? Have the Andes been mapped in detail?

A little reflection will suffice to indicate that to conquer these crests, even by air, the aeroplane will be forced to prodigious heights. It is not so much that Mount Everest tops 29,000 feet, which will demand the machine climbing to 30,000 feet at least, as the need to maintain that altitude. Unknown air currents and storms may whirl around its summit; yawning crevasses and depressions thousands of feet in depth may bar its approach by Shanks' Pony on either side. The camera must be designed to be able to meet the utmost extreme, whether it be met or not. Thus it is apparent that the development of aero lenses for aero-photographic work is, relatively speaking, only in its infancy.

Reverting to the amateur who is content to indulge in cross-country aerial sprints, his requirements are fully met. This is the field capable of extensive development, and which, from its quaint fascination, will make the widest appeal. It must be conceded that the preparation of sun-pictures from an unconventional coign of vantage possesses a peculiar and

unfathomable attraction. Moreover it is sufficiently large to present one with all the taxes upon one's ingenuity and resource that one could possibly desire. It is by no means such plain sailing, even under the most favourable conditions, as it superficially appears. The pranks played by the atmosphere will provide one with admirable scope for the practical application of individual ideas. The camera may be so designed as to be possible of operation by one who has never previously touched such an instrument, and who knows nothing about the art. The amateur may be spared all anxiety concerning focusing and stopping down. The machine may change its plate after exposure and set the shutter automatically, while the problem of exposure may be robbed of all its disappointments. Aerial photography may even be set down as rigidly mechanical. Granting all these factors, the amateur will still be confronted with peculiar problems which will occasion more than evanescent thought. In the British Isles the atmosphere is so thick, even on a fine day, as to render it difficult to obtain a photograph which does not prove maddeningly flat in appearance. The blue haze may worry him out of his senses. He can, however, cut out the selective absorption of the atmosphere by recourse to colour-filters, and this possible solution alone will extend as many searching problems as he can possibly desire. As a matter of fact, the utilisation of colour-filters to aero-photography represents a relatively new field. Their successful employment imposes a heavy demand upon the skill and competence of the photographer, and the average enthusiast will be well advised to leave them alone until he has become a master of craft. Still, they indicate a pretty tangle to unravel where success can only be built upon failure, and suffice to prove that aerial photography, despite the ingenuity displayed by the camera

builders, lens makers, and others, still presents ample scope for the exercise of brains upon the part of the would-be master of a new and strange branch of the craft.

Fortunately the terrors of the atmosphere have been largely mitigated by the platemaker. He has attacked his side of the question just as assiduously, and has evolved plates which, while not wholly dispensing with the necessity to use screens, yet enable first-class results to be obtained without them. The colour-filter need only be used in misty weather or when the atmospheric haze is particularly dense. It is the haze which is so exasperating, as I have full occassion to know. In pre-war days, when ballooning was a pastime, aerial photography, with the conventional facilities, presented many teasing and apparently insoluble puzzles; but as they have been overcome, it is superfluous to capitulate them here. The panchromatic plates which have been placed upon the market by the Ilford and other companies represent a decisive step forward, and have appreciably facilitated taking pictures from aloft.

The problems do not cease with the mere pressing of the button. The panchromatic plate introduces something new to dark-room work. It must be handled only in the dark, which means that development must be conducted with the senses, assisted by a clock, along unorthodox lines. The fact that these plates are extremely sensitive to colour renders the use of the faintest light, no matter how well screened, impossible. Development can only be conducted by time and according to the temperature of the solutions and of the dark-room itself. So far as the developer itself is concerned, any of the standard rapid formulæ now in vogue will suffice.

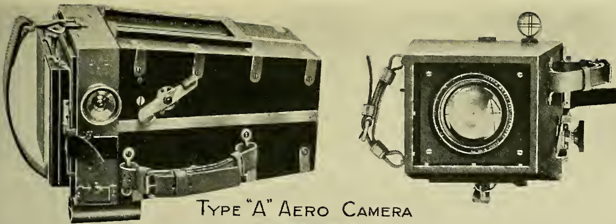
Even development will present its peculiar attractions. The aero-photographic camp is already sharply divided in

twain. The one recommends that as great contrast constitutes the value—and charm—of these aerial pictures, the best procedure is to under-develop the image to a very marked degree, and then to intensify the negative. The opposite camp maintains that strongly contrasted negatives are undesirable, and that a well-covered and graded negative, such as is yielded by the panchromatic plate, is preferable from every point of view, contrast, if especially desired, being obtained during printing. Thus the amateur can take his choice. It is possible that the pictures shown at the R.A.F. exhibition, in which contrast was very marked, attracted his individual attention. If so, he can follow the under-developing-intensification theory, and this will afford him excellent scope for his ingenuity. This was the case among the official photographers who resorted freely to dodges of every conceivable description to achieve their end, but who jealously guard the secret as to how they obtained their striking results.

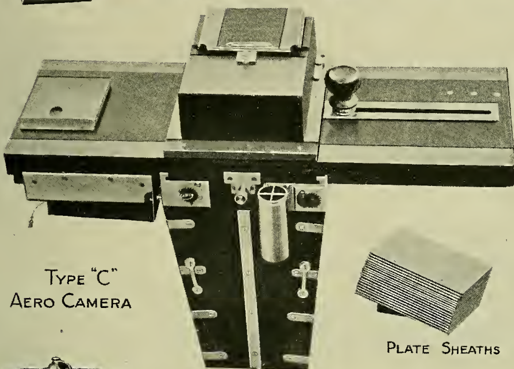
All things considered, it will be conceded that aero-photography opens up quite a new field—one in which resource, ingenuity, and patience are certain to bring their peculiar reward. It is something beyond the mechanical button-pressing system, although it is stated that a camera working upon this principle, designed for aero work and using films, is shortly to appear upon the British market. But the very difficulties and uncertainty, as well as opportunity for individual effort, will make the deepest appeal to the true amateur enthusiast. The hobby need not be unduly expensive. As I have shown, the indispensable apparatus capable of giving the finest attainable results can be secured for about £20. Armed with such an instrument the enthusiast need entertain no misgivings. The plates used are 5 inches by 4 inches, because they are a convenient unit for subsequent

enlargement, although, if preferred, the smaller ¼-plate may be employed with adapters.

Finally, it must be remembered that operations are not confined to the mere photographing of objects upon the ground. Up aloft there is magnificent scope offered for the lover of cloud effects. Then, if flying in mountainous country be possible, unconventional and strikingly picturesque glimpses of scintillating snow-crowned peaks, or sullen rain-cloud clothed summits may be secured, and with strange, albeit charming, lighting effects. Ground photography has an indescribable fascination and charm, as every amateur knows full well; but it is nothing compared with that incidental to the air and to movement in the three dimensions. Nevertheless, the greatest attraction of all lies in the knowledge that success depends vitally upon individuality, the communication of which to the ultimate picture will make irresistible appeal to the discriminating.

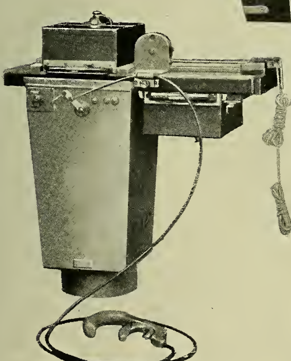


TYPE "A" AERO CAMERA

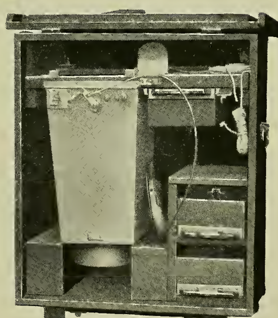


TYPE "C" AERO CAMERA

PLATE SHEATHS



TYPE "E" AERO CAMERA



TYPE "E" AERO CAMERA
IN STORAGE CASE WITH EXTRA PLATE MAGAZINES

PHOTOGRAPHING FROM THE CLOUDS

In devising cameras peculiarly adapted to the difficult conditions of aerial photography from aeroplanes British ingenuity achieved a striking triumph. In this work the instruments designed and built by the Thornton-Pickard Manufacturing Company, Limited, were supreme. Therewith the Royal Air Force took over 6,000,000 photographs during the war from heights ranging up to $3\frac{1}{2}$ miles.

CHAPTER XVIII

Exploring and Surveying by Air

IT would be interesting to know how many of those who, upon reading in the 'sixties, or even the 'nineties, of the past century the fruits of the vivid imagination of Jules Verne, as expressed in his "Five Weeks in a Balloon," did not assume the quaint wisdom of the owl, shake their heads knowingly, and, while congratulating the author upon his brilliant powers of romance, dismiss his phantasy as an utter impossibility. At the time the gifted author penned his anticipation he had little solid ground to guide him. Dynamic flight still seemed to be as elusive as the discovery of the Philosopher's Stone, while even the dirigible balloon remained more or less an unfilled ambition. Certainly the attempts which had been made up to that time were far from being sufficiently encouraging to justify the writer's manifestation of imaginative romanticism. It is not surprising that he was dismissed as a mere dreamer in so far as aerial travel was concerned, because then the ability to remain five days in a balloon, let alone as many weeks, appeared to be about as possible of realisation as the conquest of the Poles.

Yet, no sooner had the pioneers achieved their first aerial flights both by aeroplane and airship, than other writers emulated Jules Verne. They soared to greater heights of imagination than had ever been attempted by the popular romantic author, although it must be conceded that they had

more tangible records of achievement to assist them. Curiously enough they virtually took up the threads where Jules Verne had dropped them, and were quick to emphasise the value which the new method of travel and the medium traversed would extend in the rolling back of the curtain of mystery from those parts of the world which were still marked upon the map as "unknown."

At the present moment the enthusiasm manifested in this direction is even more exuberant, and it must be admitted that in the aeroplane and airship—particularly the last-named—we have a powerful force for exploring unknown or little-known territories. When one ventures upon the subject of exploration popular thoughts immediately fly towards the unravelling of the secrets surrounding the two Poles, albeit both have been reached by man. Polar exploration, however, represents merely one phase of the big issue. It is in a class by itself demanding special arrangements and deliberate, prolonged forethought as much when the two ends of the earth are sought through the air as upon foot over the hurricane-swept and scarred icefields.

For this reason Polar exploration by air will remain for some time a scientific phase of activity. The penetration of the enormous icefields offers but little attraction to commerce except in so far as mere sight-seeing is concerned. The work which can be conducted within those forbidding areas is essentially of a scientific character, although it may yield information of far-reaching auxiliary importance to commerce. The immediate application of flight to exploration is concerned with the opening up of stretches of the world lying within the zones which are capable of enabling the human race to endure. And there are immense stretches of the Americas, Siberia, China, Northern India, Australasia, and

Africa awaiting investigation—sufficient to absorb all available scientific endeavour for many years to come.

As far back as 1914 one of our barons of commerce, Lord Leverhulme, conceived the possibility of penetrating little-known territories in a preliminary manner viâ the air. He was anxious to gather further information concerning the economic value of a certain corner of Africa, especially in the contribution of oil of a vegetable character capable of being impressed into the manufacture of soap and margarine. The country in question was well-watered, but practically nothing was known about the upper reaches of these obvious channels of communication, and still less about the hinterland fringing them on either side. It was quite possible that the dense vegetation crowding upon the coastline became attenuated as the country was penetrated, giving way to final scrub and bush of the nature incidental to Uganda. On the other hand, it was equally feasible that the vegetation continued to be of that peculiar oil-nut-yielding distinctiveness associated with the coast. Close scrutiny alone could decide this point.

To have dispatched an economic exploration expedition to verify or disprove calculations and estimates would have been an expensive, tedious, and dangerous enterprise. Practically as nothing was known about the land except facts of a fragmentary nature brought by venturesome spirits who had traversed the difficult belt. This was not sufficiently illuminating to satisfy commerce. But the conventional type of expedition would have suffered from a further disability. Such undertakings, no matter how well-equipped and supported, must keep to the beaten tracks, because the jungle is so dense and tangled. This characteristic prevents the explorer from scanning the country on either side of the meandering narrow

highway for more than a few feet. A native track may be trodden down for one of two reasons—perhaps both. The one is that it represented the line of least resistance between two points, or that it may have been the shortest connecting link. The probability is that the former consideration determined the native route, as I have learned from experience in connection with Indian trails. Whatever the reason guiding the treading down of the track by passing feet it is of little or no practical value in determining the commercial value or possibilities of the adjacent country.

When one essays to fulfil such work by air quite a different aspect is imparted to the whole enterprise. For such work the airship is pre-eminently adapted, inasmuch as the pilot has full control over speed as well as altitude, while if desired he can even hover over a certain spot as long as may be required. Descent and ascent are facilitated, because both movements can be carried out in the vertical plane. At evening the vessel can descend to be anchored for the night in a clearing. As a rule such clearings are comparatively small and covered with grass or even scrub growing in profusion. When brought to earth it is a relatively simple matter to anchor the craft nose to wind, while should emergency demand a rapid ascent it may be readily accomplished.

On the other hand, the aeroplane, in its present form, is quite unsuited to the work. From aloft a small clearing may seem to be very tempting. But to come down in ignorance would be fatal. The clearing may be little more than a bog sufficiently stable to support the human body, but totally incapable of receiving a weighty aeroplane, while, of course, the grass and other growth would constitute an impossible obstacle to ascent.

Recognition of these disabilities has been responsible for

the elaboration of another idea to facilitate the utilisation of the aeroplane in such work. It is suggested that the machine should be provided with floats after the manner of the sea-plane, as well as wheels to facilitate descent upon and ascent from the water. It is urged that the machine should settle upon the water and work its way towards the bank, or be warped thereto to be anchored for the night. In this event the craft would need to carry a collapsible light canvas canoe to facilitate communication between the descended aeroplane and the bank. A towing-rope would be passed to the latter snubbed round a tree, and the crew, gaining the shore, would then haul the machine into the lee of the bank.

To those who are unfamiliar with these strange rivers such a proceeding sounds attractively simple and straightforward. As a rule, however, these rivers, particularly in their upper reaches, are extremely treacherous. He would be an intrepid aviator who would venture to come down to settle upon some of the big waterways, say, of Canada, such as the Peace, Fraser, Athabasca, Skeena and other rivers in the unknown north-west. From a distance they appear to be quiet, well-ordered waterways, their extreme width contributing to the prevailing appearance of perfect serenity. But the moment the machine struck the water a heavy tax upon navigating prowess would be imposed. Naturally the aviator would make for the centre of the river to secure the advantage of elbow room. This very temptation would lead to his undoing, because in the centre the river is a fiercely-scurrying maddened surge of water. It swings along at a vicious pace, and is more to be dreaded in summer, when weather conditions are ideal for flying, than at any other time of the year. Some of these rivers are little more than torrents, though superficially there is nothing to betray their mad haste to get to

the sea. The Skeena river in North British Columbia may be cited as a typical instance. During 180 miles of its run it falls about 700 feet. The steamboats have a hard task to pick up a landing stage en route. They fly past the stopping point, slow down, turn round, and then chug laboriously up stream. At one minute they are travelling twelve to fourteen miles an hour easily, because the stream is with them. The next minute they are going all out to crawl forward at two miles an hour. "You can come down from the Skeena in two days, but it may take you a fortnight to get up" is the colloquialism of the navigators who know every inch of this waterway; and it is more or less applicable to every other waterway not only in Canada but other countries.

In such circumstances one can readily imagine the plight of even a skilled pilot in attempting to make a descent upon the water. Landing with the stream, the pace of the current which it is impossible to determine except by the "feel," since it varies from hour to hour, the aeroplane, deprived of its independent speed as supplied by its motors, becomes the sport of turbulent waters to be hurled forward. In all probability it would founder within a few moments. Certainly herculean effort, uncanny skill, and a liberal dash of luck would be required to regain its control.

Supposing the pilot were suspicious and decided to land against the stream. He would need to keep his machine under the most extremely delicate control, and would have to hit the water in the manner of the flat stone thrown by the boy in his game of ducks and drakes. The moment of impact would serve to convey to him whether his engine was running at sufficient speed to off-set the strength of the current, and the hand would need to be highly sensitive to resolve this point to a nicety. Pre-supposing it was deter-

mined, then the engine speed would have to be carefully maintained while definitely settling, and then be kept going until the shore was made with the rope, when delicate manœuvring would have to be displayed to work the craft gradually inshore to gain the shelter of the bank. Unremitting care would need to be observed to prevent the machine swinging sideways. If it did so disaster swift and sudden would overtake it. The moment the floats turned a trifle broadside they would be whipped round by the current, and the water would pile up the side, thus forcing the machine over.

Getting off would be far more exciting and dangerous. The machine would need to taxi up stream, the engine power developed being adequate to take into consideration, and to allow for, the swing of the water. Indiscriminate taxi-ing up these waterways is impossible. The main channel is generally littered with hidden dangers in a variety of forms—snags, boulders, sand-bars and what not, with reaches of rapids thrown in to add to the difficulties and complexities of navigation. The chances are that if a pilot ever did succeed in getting down safely he would be unable to rise. Moreover, he has not only the treachery of the water beneath him to bear in mind, but the fickle wind currents as well. These whistle through the rift formed by the waterway as through a funnel. Sometimes they are in opposition to the water; at others they are in alliance; at times they swing viciously at an angle across the stream; while they chop and change with the most amazing capriciousness. In so far as penetration of these difficult territories is concerned, landing would have to be made upon a lake, either an isolated sheet of water or the winding of a river, care being exercised in the last-named event to select a site clear of the main channel. This would

be particularly essential among the mountain ranges, for in these regions the water is generally compelled to drive its way through a constricted passage, and in times of flood will even sprawl over the adjacent low-lying ground. Then, with characteristic fickleness, it splits up into half a dozen fairways of identical viciousness.

Fortunately all these backwood waterways are not so treacherous. Some are quiet, ordered, and slow-moving, but they are the exceptions which prove the rule. Generally speaking it would be advisable for the pilot to consider these up-country rivers, even when flowing in an apparently sluggish manner through level country, with suspicion; they are always more dangerous than they appear. The assistance of local guides, who may be trusted to know these waterways, should always be sought, and, as a rule, the resource of the man upon the spot, conversant as he is with prevailing conditions, will be found a reliable reed upon which to depend, although his ways of achieving a desired end may not always meet with approbation.

The exploration of the lesser known parts of Canada by aeroplane, notably the inner parts of Ungava, and the more northern reaches of the Yukon Territory, has been suggested, but is regarded with mixed feelings by those competent to express an opinion. Before attempting the work it would be necessary to prepare a detailed map showing the situation of the scattered posts of the various trading companies. The fact that these trading posts are established may serve to prompt objections against carrying out any exploration flights at all, but it must be explained that these posts are chained up by communicating tracks, and that very little is known beyond a few miles around each post. Native villages would also need to be indicated, either beforehand, or in the course

of preliminary investigations by air, and committed to the map.

The reason for such precautions may be explained. As a rule, ample clearings have been made around each post and village, the timber having been felled to provide firewood for the isolated factor or community. These clearings for the most part are tolerably level, while in many instances there is a relatively straight and wide wagon road approach to the post. This narrow track would have to be used, as a rule, for landing and rising, because the adjacent country, while clear and level, may prove a snare owing to the stumps of trees remaining in the ground. Collision with the butt of a Douglas fir, or even cottonwood tree, having a diameter of three feet or more, would not fail to leave its mark upon the aeroplane. Nevertheless, a little preliminary work would generally serve to convert the clearing into a passable aerodrome.

Such a trading post or village could be selected as the base for operations, a circle being drawn round each, at first of relatively short radius, but extended as the general local conditions became mastered. From varying altitudes the general lay-out of the country for miles around could be determined, due record being made of the openings in the interminable expanse of timber. These "little prairies," as they are termed, would need to be regarded with caution and to be inspected, for many are but muskeg, landing upon which two or three hundred miles from the base would certainly imperil the aviators. The unlucky crash which the Vickers-Vimy machine experienced upon landing in Galway after crossing the Atlantic suffices to emphasise how misleading a bog appears when regarded from aloft.

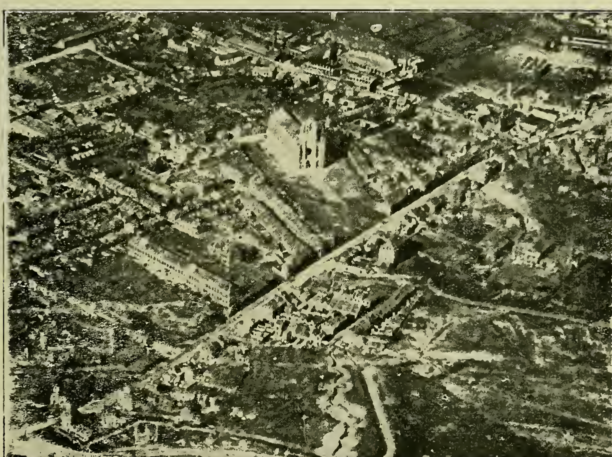
Density of timber is likely to render exploration of new or little known territories lying within the temperate zone a

matter of extreme hazard if the aeroplane be employed. Of course, when the dynamic flying machine becomes invested with the capacity to ascend and descend vertically, as well as being possessed of the power to hover, these dangers will disappear. But until such time the investigation of such areas lies rather within the province of the airship, and it is this vessel which will be most extensively employed for this work.

Exploration to be of any material value to science and commerce must be carried out with care and precision. For the fulfilment of such work speed is a secondary factor, if it be not actually a handicap. Up to approximately seventy miles an hour the airship is overwhelmingly superior to the aeroplane, while, of course, there is extreme latitude for the lighter-than-air machine between the zero and maximum. The speed of the aeroplane cannot be safely reduced below a certain pre-determined limit, which, for the most part, is far in excess of the requirements of the work which is to be achieved. Radius of action upon a single fuel charge is far more vital than mere speed, and at slow cruising speed, say at twenty miles an hour, or even less, the airship would be able to remain out upon a specific duty for several days and would be able to satisfy the creature comforts of the party in regard to commissariat and sleeping as well as camping facilities meantime. The airship, by being lowered to the ground and safely anchored, may even be used as a mobile camp. Accurately moored in a clearing the average storm might be viewed without anxiety inasmuch as the surrounding forest would serve as an excellent wind-screen.

In so far as Polar exploration is concerned, the aeroplane would probably prove the more advantageous, at least for the purposes of completing what might be described as the

A PICTURE TAKEN DIRECTLY VERTICAL, GIVING PLAN EFFECT



Official R.A.F. Photographs.

A PICTURE TAKEN OBLIQUELY

PHOTOGRAPHY FROM THE AIR WITH THE THORNTON-PICKARD AERIAL CAMERA

preliminary runs, or for generally spying out the country, the airship being subsequently utilised for completing the more detailed investigations. The difficulties are more intense in this field of application. One has only to read the absorbing and thrilling stories of the experiences of explorers within the Polar regions during the past twenty years to be able to form some idea of the problems which would need to be solved and the dangers to be surmounted. Low temperatures, such as are to be expected, are really but the least of the perils. It is not impossible to subjugate these, though the task would be simpler with the airship than with the aeroplane. The power plant, as represented by the engine, radiators and all auxiliary gear, as well as the fuel and lubricating oil tanks, would have to be enclosed in a special housing, as well as being covered for protection against the attacks of King Frost. The apartments or engine-rooms would also need to be maintained at an even temperature to ensure the smooth even running of the motors and water circulation, as well as steady fuel and oil feeds. It would probably be found expedient to resort to electric heating, necessitating the installation of a small electric generating plant, together with accumulators, science not having yet solved the problem of storing heat after the manner of electricity, although, if such an achievement ever be placed on record, it will go a very long way towards solving the problem of easy, quick and safe exploration of the Polar regions by air.

The perfection of means for heating clothing by the aid of electricity has also solved the task of equipping the members of the party with garments which would enable them to pursue their respective tasks in comfort. When one bears in mind the circumstance that the temperature is so low as

to cause the skin of the hand to adhere to exposed metal with which it may chance to come into contact, and to provoke a sensation analogous to that produced when seared by a hot iron, one may possibly gather some idea of the advantage accruing from the provision of electrically-heated clothing, especially of gloves and moccasins. Under airship conditions, the supply of the requisite current for this purpose, as well as the heating of rugs and carpets within the cabins, will be appreciated.

The blizzard and the boisterous winds encountered in the Polar regions constitute the greatest dangers. The aeroplane, from the circumstance that it offers a smaller area of resistance to the wind and presents a smaller refuge for snow, would be at a distinct advantage as compared with its lighter-than-air contemporary, although the deposit of a thick layer of snow on the planes and the dependence of icicles from the spars, wires, and fuselage would constitute a serious encumbrance, as well as increasing resistance to the air. If one bears in mind the enormous bulk of the airship, one will readily see that in this instance the weight of snow accumulating upon the body of the bag might easily become sufficient to destroy all lifting effort, and so bear the ship to the ground. Again, the enormous area which it would present to the fierce Polar storms would represent a distinct handicap if not actual danger.

Yet it is imperative that Polar exploration by flying machine should be carried out if at all within the achievements of man. In this way, and this way only, will it become possible to widen our knowledge concerning the upper reaches of the atmosphere as it prevails above the ends of the earth. It would enable us to remove much speculation prevailing at present concerning terrestrial magnetism and electricity, as

well as providing the means for the investigation of the phenomena of the Aurora Borealis and the Aurora Antarctica from quite a new and novel point of vantage.

Even from the pleasure point of view, new opportunities for sensation, thrill and wonder are opened up. When the air conquest of the Atlantic and Pacific Oceans becomes as commonplace as their negotiation by liner, we may look forward to aerial trips to the North Pole. To-day it may sound fantastic to suggest such a journey, but it is well within the range of possibility while the human race is by inclination ambitious. Exploration and surveying expeditions conducted in safety will immediately suggest the inauguration of joy-riding trips, so that the day of Cook's Tours to the North Pole may really not be so ridiculously remote as it appears. Seeing that the lure of the midnight sun tempts thousands to make runs so far north as Spitzbergen, while even trips to the fringe of the forbidding north Polar ice sea are conducted under favourable conditions during the summer season, it is safe to assert that the practicability of being able to reach the top of the earth and to witness the gorgeous display of terrestrial electric pyrotechnics will prove equally irresistible. It will not be a dangerous or tedious journey. Suitable sites for aerodromes exist at Spitzbergen and Nova Zembla, while aeroplanes might be employed for service as feeders between the mainland and these remote airship termini. The round trip to the North Pole would occupy no more time than the run from Newfoundland to Ireland. It might be completed in twenty hours under favourable conditions and without unduly pushing the vessel. The trips could be so timed as to bring the wonder-seeking and curiosity-provoked passengers to the Pole at the hour when the most magnificent natural spectacles might be anticipated. It may safely be

stated that such trips would become one of the most sensational and thrilling which this rapidly shrinking sphere would be able to offer.

So far as the South Pole is concerned, it is likely to remain an unconquered tourist field for many years after the routes to the North Pole become established. The remoteness of the bottom of the earth, the great span of the Antarctic Ocean dividing it from the belt of accepted civilisation, and the relatively sparsely settled character of the countries under the Southern Cross will somewhat react against the rapid development of a comparative idea in regard to the South Pole. The conditions are not so favourable for the establishment of aerodromes as at the top of the world, although in so far as this issue is concerned it is quite possible that aerial investigation of the territories bordering the Antarctic Circle, notably the Southern Shetland Islands and MacQuarie Island, may prove of far-reaching assistance in this connection. The Northern Hemisphere is more densely populated; of its own initiative it is seeking more and more elbow room in a northerly direction, and the outposts of civilisation have been pushed well beyond that indefinable scientific line of demarcation which we popularly call the Arctic Circle, so that conditions are more favourable to the aerial conquest of the top of the earth and its ice-cap.

Commerce and trading follow hard on the heels of the explorer, who has but to dwell briefly upon the economic resources of the country which he has penetrated to fire the imagination and enthusiasm of those who would turn the trading possibilities of Nova Terra to account. The pathfinders set out to discover lines for railways, tracks for telegraph wires, sites for towns and mills. This is work which from its very nature must be conducted with care and ac-

curacy, since the efforts of the trail-blazers constitute the foundation for the subsequent commercial and industrial fabric. The work accomplished by the explorer, often of a perfunctory character, has to be verified and amplified. Accordingly, surveys must be conducted along well ordered and elaborate lines. It is a task every whit as exciting as that of the exploration, because it necessitates venturing into new territory with its untold dangers, thrilling incident, and preparedness to cope with the unexpected.

It is expensive and tedious withal. Take the building of a railway or the plotting of the path for the telegraph through a new territory as a case in point. The maps are necessarily scanty and but indifferently prepared—possibly they carry only the hazy details outlined by the explorer. When the surveyor sets forth on his mission he comes full tilt against error. He finds that rivers are indicated miles out of their true course, and that mountains have been recorded where they do not exist. Consequently he takes little for granted. Difficulty of movement, whether it be through thickly wooded country or over sweltering plain and desert, demands that his equipment shall be reduced to the absolute minimum, while elaborate precautions have to be observed to ensure supplies of food being within his reach at all times.

Some idea of the arduous labour confronting the railway surveyor under contemporary conditions in plotting out a path for a new railway may be gathered from the fact that the selection of the route of the Grand Trunk Pacific Railway through the Rocky Mountains of Canada involved tramping afoot over 10,000 square miles of scarcely known country. The flying survey, as the first investigation is called, when the surveyor strikes his route by aid of his compass and roughly paces his distances, was carried out by one man

accompanied by an intrepid Indian scout. Each carried his bed in the form of a blanket upon his back, while the twain depended in the main upon the game which fell to their rifles and to their carefully-prepared traps in the rivers, for their existence. They wormed along narrow crevices scarcely wide enough to receive their two feet, often precariously poised hundreds of feet above a raging mountain torrent. They either swam the rivers or crossed them upon frail rafts hastily fashioned from logs crudely lashed together with willow thongs. For months at a time nothing was heard of them; facilities for communication except through the medium of a passing Indian hunter or wandering trapper were impossible.

Contrast this method of running the flying survey with that which is now opened up viâ the air. The most difficult, thickly forested country, laced with the most tumultuous rivers, the most sun-scorched desert, can now be examined in comparative comfort and in safety from an excellent coign of vantage. By means of the aeroplane, using the most advanced trading post as its base, hundreds of square miles of country can be examined within the space of a week. If the airship be employed the speed can be slowed down to walking pace, and as often as required it can be brought to a standstill, the propellers running at just sufficient speed to off-set the wind, poised but a few score feet above the ground. The whole of the country can be photographed, and from the built up panorama a complete bird's-eye view of the topography of the ground, true to scale, may be examined at leisure.

In so far as the application of photography to surveying is concerned, there is one peculiarity which will demand careful consideration. Direct vertical pictures, as explained in another chapter, yield merely flat pictures in the horizontal

(1) THE VICTOR OF THE TRANSATLANTIC FLIGHT; AND (2) 30,500 FEET UP!

1. The "Vickers-Vimy"-Rolls aeroplane, in which Sir James Alcock and Sir Whitten Brown flew the Atlantic.
2. The "Airco" biplane which rose to a height of nearly six miles in 66 minutes 55 seconds.

plane. Variations in the contour of the land are not shown, or if so, only imperfectly. It is difficult to assess relative heights and depths. A more realistic picture is obtained by taking an oblique photograph, but this presents another problem. Distortion becomes somewhat pronounced, and is capable of playing many strange and bewildering tricks. A natural object, such as a hill or a wood, may be photographed from twenty or more different points and give as many different pictures, no one for a moment, unless otherwise instructed, being able to associate the many pictures with the one object. This peculiar distorting property is one which at the moment is occupying close scientific attention. It is generally recognised, that, until it is overcome, or at least mitigated very perceptibly, photography will only be able to play a minor part in survey work from the air; at all events, in the oblique sense.

In difficult country aerial communication would be useful for the movement of instructions and provisions between the base and the advanced survey camps. The parties, as a rule, are limited in number, some being composed of only six to eight men. The general practice is to utilise pack animals for the transport of foodstuffs and other impedimenta, but such movement over narrow wearisome trails is slow. With aerial communication the movement of the camps would be expedited and the whole task appreciably speeded up. The distance to be traversed for the most part is relatively insignificant, ranging up to about 120 miles from the base to the most advanced camp. The establishment of quicker transport and communication facilities would enable a greater volume of work to be accomplished in a given time, a matter of supreme importance in territories where the open season is relatively brief.

The association of the aeroplane and airship with survey operations would not be confined to the plotting of railways. It would be equally useful for the driving of trails and wagon roads, telegraph lines, the conduct of geological, economic and mining surveys, as well as the delimitation of frontiers. In work of this character appreciable delay is often incurred in the transmission of information and instruction, for the reason that the only available Mercury is the packer or native guide and his four-footed mount, or canoe should water connection be available. In many instances all messages are conducted on foot, which, strange though it may seem, is often the quickest. But inasmuch as a week is likely to be occupied in traversing, say, 120 miles, the distance between the advanced camp and the base, it will be seen that progress is exposed to serious delay upon those occasions when the man in the field is anxious to receive further instructions from his chief at the base. From fourteen to twenty-one days at least will be required to complete the round trip, whereas, viâ the air it could be carried out satisfactorily in a few hours. Obviously, therefore, a great future awaits the development of the aeroplane and its consort in this important field of human endeavour.

CHAPTER XIX

Dirigible Airships for Trans-Oceanic Traffic

WHEN will the airship service between Britain and America be established? This is the question which naturally arises in view of the momentous trans-Atlantic voyage of H.M.A. *R*34. It was an epoch-marking journey in every sense of the word, especially the homeward run from New York to Pulham, Norfolk, since this was made more or less under normal conditions, along what may be described as the great trans-oceanic aerial lane, the 3,000 odd miles being covered in 3 days 3 hours 3 minutes. The climatic conditions were such as might safely be anticipated, if not every day, at least at intervals. The independent speed attained perhaps was not unduly high, even after making allowance for the breakdown of the astern propelling unit, inasmuch as no attempt was made to push the vessel, or to inaugurate a commercial schedule. But, at the same time, it was not appreciably longer than would be occupied by such a craft as the one in question, which has not the turn of speed possessed by her consorts in this class, and certainly does not approach that with which craft designed for everyday commercial duty would need to be provided.

The day when the Atlantic Ocean will be spanned by fleets of huge dirigibles—aerial liners in the fullest sense of the word—is not so far distant as one might possibly assume. There is every indication that regular services will be in

at 128·26 tons, while the total weight of the ship, ready for flight, including fuel, oil and other accessories, is 107·7 tons, leaving 20·56 tons available for provisions, water, passengers and crew. The propelling equipment, following the lines embraced in connection with H.M.A. *R*34 and her consorts, comprised 5 units disposed in 4 gondolas, and with the fifth engine at end of the corridor.

To indicate the advance which this vessel represented over the naval rigid vessels now in commission and which were under construction when the plans for the Transatlantic liner were prepared, the essential dimensions of the *R*34 and *R*32 are given for comparison.

	*R*34	*R*32
Length	643 ft.	615 ft.
Maximum diameter	78¾ ,,	65½ ,,
Total capacity	2,000,000 cub. ft.	1,550,000 cub. ft.
Total lift	60 tons	47 tons
Disposable lift	29 ,,	16½ ,,
Total brake horse power	1,375	1,500

From these figures it is possible to realise the degree of advance which the projected Transatlantic liner represents, the capacity being more than twice that of *R*34. As already stated, these plans were completed many months before *R*34 made her sensational voyage, and, as a result of the experience which was acquired during the construction of *R*32 and *R*37, both of which were carried out at Cardington under his direction and supervision, Mr. Mitchell has been able to amend his proposals, his revised ideas providing for an airship having a total capacity exceeding 8,000,000 cubic feet of hydrogen. To the uninitiated the advance from 4,450,000 cubic feet to 8,000,000 cubic feet capacity may seem

to savour somewhat of the prevailing Teuton grandiose precept of the "kolossal," but it must be remembered that in airship construction, as in naval designing and the elaboration of plans for mercantile vessels, the designer is always far in advance of actual practice, and that development and evolution to larger, more powerfully-engined, and faster craft must inevitably prevail. When commercial airship construction settles down into its stride the pace will be found to be rapid, and for many years each succeeding vessel will represent a decided forward step in all essential dimensions and requirements.

In so far as the Short-Mitchell proposal is concerned attention may possibly be attracted to the speed, which is set down at 60 knots. To some critics this will seem to be high; to others it will be maintained as too low. But in elaborating his plans the designer has been governed by certain vital considerations. In the first place, speed costs money; so to crowd a high engine equipment into a vessel in order to satisfy the craving for speed is not only going to add very appreciably to weight, to the detriment of passenger-carrying capacity, but must also affect seriously the revenue-earning factor, and at the same time is going to enhance the fuel consumption item. I will refer to this again a little later.

To bring about the reduction of engine weight to the minimum consistent with economical fuel consumption the designer must furnish the vessel with adequate power to enable it to take to the air and to conduct its journey under the most adverse weather conditions. If the airship is going to be considered merely as a fair-weather craft then it cannot possibly possess any commercial value. Business and trading exigencies demand that the vessel shall be competent

to serve under all weather and wind conditions. It must start at the scheduled time; must be as punctual as the railway train and ocean liner. Of course, there are occasions when even marine vessels are delayed in starting by exceptionally adverse weather, but they are very rare, and the weather must be extremely heavy to bring about a decision to postpone starting even for a few hours. The great steamship companies pride themselves upon their punctuality in starting, and any airship service wishing to achieve popularity must be equally prompt.

To bid defiance to the weather the engine power must be adequate to rise superior to all wind conditions, and, in planning the propelling equipment the designer must carry out his calculations with the worst conditions as his standard. If we consult the Beaufort scale of wind force we find that No. 10 on the scale, a whole gale, which is occasionally experienced in the Atlantic, has a mean velocity of 59 miles —not knots—per hour. The storm and the hurricane being freaks of wind force may safely be eliminated, as they are very rarely experienced and represent conditions under which no vessel, either in the air or upon the sea, could hope to battle. So the whole gale may be accepted as the worst likely condition and as a precautionary measure against which engine power must be designed. On this basis the trans-Atlantic liner would have an approximate balance of power over the wind of 8 miles an hour—the knot is estimated as equal to 1⅛ mile—which, while not being very pronounced, would enable the vessel, with her engines normally all out, to hold her own against the gale, that is presupposing the aviator considered it to be advisable to attempt to drive forward.

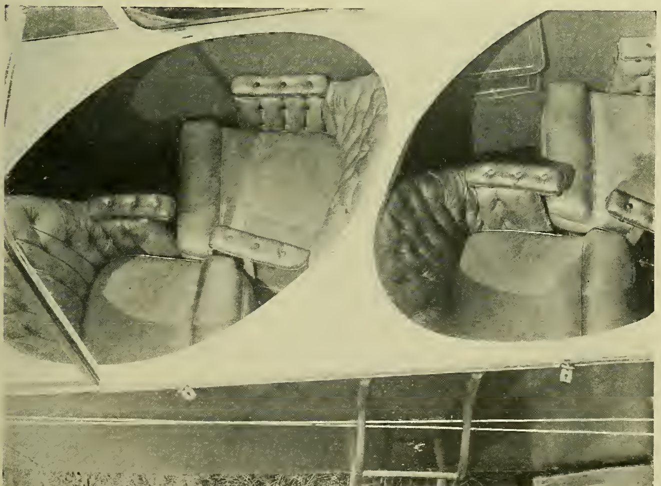
Of course, the designer might provide a bigger margin

or balance of power, but in doing so he would have to sacrifice economy of running, disposable lift, and incur heavier fuel consumption. The fuel question is one of the most perplexing problems in airship design. Certainly it occurs in connection with the ocean liner and the railway express train, but to a lesser degree. Petrol is weighty—far more so than might be imagined, perhaps. In connection with the airship under description the fuel necessary to secure a radius of action of 6,000 sea miles at 60 knots weighs no less than 44 tons! It is the most difficult individual factor in the whole problem. Of course, the uninitiated will probably remark, seeing that the distance between England and New York is only approximately 3,000 miles, that the radius of action might be reduced. But can it?

Let us reflect a moment. We will suppose that a high wind, corresponding with No. 7 on the Beaufort scale, is raging when the airship sets out. I might have taken the whole gale once more for this illustration, but I have purposely selected the high wind for the simple reason that the former might only last a few hours or its zone be negotiated within a few miles, whereas the latter might be encountered throughout the whole of the journey across the Atlantic, as mercantile experience abundantly testifies. Now the high wind, according to the Beaufort scale, has a mean velocity of 35 miles an hour. The margin of power possessed by the airship would thus be 32 miles an hour. Consequently, during the trip she might not be able to average more than 32 miles an hour the whole way, although her engines were developing the designed 60 knots. If perfectly calm weather prevailed throughout the run the airship would be able to remain in the air for 100 hours when travelling at 60 knots, because her 44 tons of fuel would

suffice for 6,000 knots under such conditions. So if we divide the 6,000 by 60 we get the time-period or endurance capacity of the vessel upon the one fuel charge, with engines normally all out, which is 100 hours; but, owing to the persistence of the adverse high wind, blowing at 35 miles an hour, the airship is really only able to make headway at about 32 miles an hour, this being her independent speed. The distance between the two ports is 3,000 miles. Consequently, if we divide this figure, 3,000, by the independent speed of the airship, 32, the result is the time which will be occupied upon the journey—94 hours. In other words, she will be called upon to remain in the air for 94 hours, whereas the limit of her endurance, under the most favourable conditions conceivable, is only 100 hours. Thus the margin is not so pronounced as it might at first sight appear; hence the reason for the designer observing all precautions and taking the adverse conditions into full consideration when making his calculations. It is not to be supposed that the adverse wind would be encountered the whole way across, but such *might* be the case, and it is the contingency which must be borne in mind. When talking about speed in connection with aerial travel confusion is likely to arise, but it is imperative to master this issue as emphasised in another chapter. It is only the independent speed of the airship which counts. How serious a factor this is, and how urgent is the necessity to make allowance therefor, was borne out very pronouncedly upon the occasion of the outward journey of *R*34. Her fuel tanks carried 4,900 gallons of petrol, which should have sufficed to keep her in the air at a speed of 47 knots for 75 hours. As results proved, the supplies were barely sufficient, because at one time it was thought that the vessel would have to be taken in tow for a certain

The passenger aeroplane built by the Aircraft Manufacturing Company, Limited, showing collapsible hood to cabin, and method of boarding the craft.



Vis-à-vis seating arrangement which enables the available space to be turned to greatest advantage to the comfort of the passengers.

BY AIRCO BETWEEN LONDON AND PARIS

distance, allowing the remaining few gallons of petrol to be used to permit the airship to gain her harbour.

To bring home the influence of speed upon fuel consumption I will interpolate a few facts concerning the actual performance of *R*34. With all engines running the fuel consumption at varying speeds is as follows:

At	47	knots	petrol	consumption =	65	gallons	per hour
"	42	"	"	"	50.8	"	"
"	36	"	"	"	47·4	"	"

Only a cursory glance at these figures is required to show the most economical speed of the airship. To obtain an extra six knots—36 to 42—only an additional 3·4 gallons of petrol per hour are required, but to squeeze out the last five knots, and thus secure the normal full speed of the airship—42 to 47 knots—entails eating into the fuel supplies to the extent of an extra 14·2 gallons per hour. It is the old, old story: it is the last knot which runs away with the fuel. Obviously, therefore, the most economical speed for *R*34 is about 40 knots, which is distinctively known as the cruising speed. But this, as events proved, is cutting things rather fine.

Reverting to the Short-Mitchell airship we see that the speed selected is not only one which is likely to prove the most effective and economical from the all-round point of view, but that it is one affording the commander just that little up his sleeve which he must possess to hold his own against the tempestuous weather incidental to the Atlantic. What at first sight appears to be an extremely liberal radius of action, 6,000 nautical miles, upon examination proves to be none too much. It must not be forgotten that an airship

service, to pay its way and to become an established commercial success, will have to be run both winter and summer. So in elaborating his scheme the designer must make due allowance for the most adverse conditions.

Of course, even with this radius of action it is quite possible that the weather encountered might prove to be so consistent and exasperatingly adverse as to render it insufficient. But the vessel would not be imperilled. She would merely summon assistance by her wireless, swing round nose to the wind, and settle at a low height above the water, riding freely with her drag anchors thrown out until succour came. If such extreme action were imperative the commander would take care to retain two or three hundred gallons of petrol in his tanks. Possibly, if the weather moderated and a tanker came up, she might be able to take on a further supply of fuel to enable her to reach her destination, but this is doubtful. It is probable that she would be taken in tow until approaching her destination, when, casting off the towing ropes, she would rise once more into the air to complete the last lap of the journey under her own power with the remaining supplies of fuel, which would also enable her to manœuvre over her harbour to complete actual landing. The airship would never settle actually upon the water, since in so doing, she would become exposed to hogging and sagging strains from being poised upon two waves at once, and would inevitably break her back under her own weight. But she would be able to come down to within a hundred feet or so, and her special anchors—drogues made of canvas in the form of a truncated cone—would enable her to ride in safety nose to the wind, even in the roughest weather, because she would offer the minimum of resistance to the wind and, by virtue of her inherent

lifting capacity, would continuously exert the tendency to rise, but be held in complete check by her drags.

In preparing her designs Mr. Mitchell has gone thoroughly into every detail. The weights of the individual parts of the ship have been closely estimated, and these are given as follows:

Main Structure

Longitudinal girders	3·2 tons	
Transverse girders	5·3 ,,	
Diagonal wiring	2·81 ,,	
Circumferential wiring	1·55 ,,	
Cord wiring	·50 ,,	
Lift and axial wires	·64 ,,	
Total weight of structure		14·00 tons
Gas bags	9·25 tons	
Outer cover, including ridge wires	3·78 ,,	
Gondolas, engines, petrol and oil systems	16·1 ,,	
Fins, rudders and controls	1·88 ,,	
Corridor and fittings	12·7 ,,	
Miscellaneous	·99 ,,	
		44·7 tons
Total fixed weight of airship		58·7 ,,

The foregoing represents the total dead weight of the ship in the empty condition. Before leaving this side of the question it is interesting to observe the weight of wire introduced into the hull and inner structure, which in the aggregate exceeds 5½ tons, or nearly one-twelfth of the total weight of the empty vessel. When one bears in mind the fineness of the wire which is used, one commences to realise the important part which wire plays in the fabrication of the

airship, since, in the continuous length, it would represent a few dozen miles.

To the foregoing must be added the "live" weight of the vessel, that is, the weight of the passengers and crew, provisions, water, fuel oil, and other numerous accessories which do not enter into the actual construction of the vessel, and which may be more accurately described as the load or its equivalent. This is given by the designer as follows:

Disposable weight

Weight of 50 passengers (160 lb. each)	3·57 tons
Weight of 35 crew (160 lb. each)	2·50 ,,
Passengers' baggage (100 lb. per passenger)	2·23 ,,
Crews' kit (30 lb. per man)	2·46 ,,
Water (1 gallon per head for 10 days)	3·8 ,,
Provisions (8 lb. per head for 10 days)	3·0 ,,
Mails	2·0 ,,
Cutlery, etc.	·8 ,,
Miscellaneous	·16 ,,
Water ballast	2·0 ,,
Petrol	44·0 ,,
Total disposable weight	64·52 tons

Thus the total weight of the ship, ready for the air, which is the sum of the fixed and disposable weights, is 123·2 tons, while the total lift of the ship, with the bags inflated with hydrogen to 95 per cent. of their full capacity, is 128·2 tons. This itemisation of the weights of the various factors concerned emphasises very convincingly the significance of the weight of the fuel, this being one-third of the total weight of the craft laden ready for its journey. Of course, the airship, in common with the steamship, becomes lighter hour by hour during the journey from the consumption of fuel and

provisions. At the end of the estimated 10 days the total weight would be reduced by some 50·8 tons, that is premising all provisions, water and fuel were exhausted. But, at the same time, the lifting capacity of the ship would be somewhat lower than when she started on her voyage owing to the loss of hydrogen, this varying with the temperature experienced and the altitude to which the commander might be compelled to go during the trip. As is well known, rise of temperature is attended by expansion of the gas. If there should be twenty bags each bag would be inflated to within 5 per cent. of its full capacity, so that the margin extended to absorb this expansion would not be appreciable, and in practice would be speedily exceeded, especially when increase in temperature might be accompanied by necessity to rise to a high altitude, because increased density of the atmosphere also plays its part in the expanding tendency of the hydrogen. Consequently, although the weight of an airship is steadily and continuously diminishing during the journey so is its lifting effort, though not to a proportionate degree.

In preparing his plans the designer has departed somewhat strikingly from the lines laid down in connection with the "R" class of Service airships. The latter are more or less slavish reproductions of the Zeppelin rigid dirigible, but experience therewith has indicated the possibility of introducing several modifications which would appreciably enhance the strength, safety and general all-round efficiency of the craft.

Externally, divergence from Teuton practice may not be very striking, but in so far as the structural details are concerned there are many decided improvements. Instead of spacing the girders somewhat closely together, as is the Service practice, in the Short-Mitchell trans-Atlantic airship they

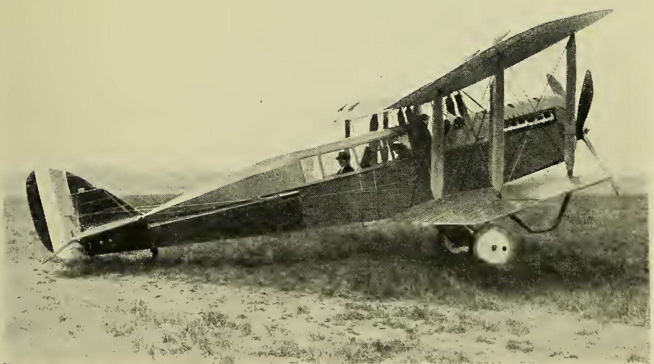
are fewer in number and consequently are spaced wider apart; but this enables the girders to be made proportionately stronger, thereby extending greater safety against local damage. The transverse and longitudinal girders are also designed to take longitudinal and sheer stresses in the main and only small distorting stresses caused by varying conditions. All redundant parts are eliminated so that the stresses become definite in any given condition. To compensate for the wide spacing of the longitudinal girders longitudinal wires are introduced between the latter to support the outer cover. The diagonal wires are also placed *outside* the girders instead of inside as at present practised, so as to be clear of all pressure exerted by the gas-bags. Another improvement upon the current practice is to transfer the main gas pressure from the rigid structure to circumferential wires and lift wires from re-entrant angles at the top.

Probably the most striking deviation from contemporary ideas is in connection with the design of the gas-bags themselves. Instead of being drum shape they are given pear-shaped ends and are supported by loose wires. The curvature of the ends of the gas-bags and the disposal of the wires are carried out in such a manner as to obviate all distorting stresses under the average condition of pressure.

As a matter of fact, the improvement in the design of the gas-bags constitutes one of the outstanding characteristics of this vessel, and is indicative of the study which has been brought to bear upon this important factor as a result of many years' experience upon the part of Messrs. Short Brothers, Limited, concerning the action of gas when at work, as in imparting ascensional effort to a balloon. The hydrogen, being lighter than air, naturally strives to rise,

FLYING DE LUXE

The comfortable and spacious cabin of the Vickers commercial aeroplane



FOR CIVILIAN FLIGHT

The "Airco," with enclosed cabin, which inaugurated civilian flight between the British and French capitals.

but in so doing finds itself obstructed by the walls of the bag. Gas, however, is compressible, and so despite the restraining influence which it encounters does persist in obeying the natural tendency to rise to the top of the bag, leaving the lower part somewhat flaccid. In these circumstances the pressure exerted upon the bag is not uniform. It attains its maximum at the top, while the minimum is at the bottom. In the early French dirigible experiments—a similar practice must be observed to-day with airships of the non-rigid type—a ballonnet is introduced. This becomes inflated with atmospheric air and consequently distended. In so doing it tends to equalise the pressure upon the gas-bag by keeping the lower part, where the minimum pressure is exerted by the hydrogen, at full extension.

In the rigid airship the strain imposed cumulatively upon the top of the structure from the contents of possibly twenty bags is likely to become somewhat pronounced, and the unequal pressure thus exercised introduces bending moments and other distorting stresses in the supporting structure, which can only be counterbalanced to a certain degree by the tension of radial wires. Under the new method of constructing the bags along the lines which have been evolved, thereby giving them semi-hemispherical or pear-shaped ends, the circumferential tension in the fabric, and also of the circumferential wires or frames under average condition of pressure, are kept constant, thereby eliminating the necessity to introduce most of the radial wires. This in turn reduces the pressure on the longitudinal girders and the bending moment in the frames. The whole of the lift of the bags is taken by the circumferential wires, which are secured at the lower ends only, and the lift wires, which are led from the re-entrant angles to the corridor where most of

the weights are concentrated, or to the gondolas at the sides. The lift wires are passed through the bags, so that in the event of a bag being deflated the tension on the wires suffers no undue increase. By virtue of the arrangement which has been carefully evolved, the distorting stresses imposed upon the rigid framework of the vessel, due to the gas pressure, are virtually eliminated, thereby releasing the girders to fulfil their primary function—namely, the provision of longitudinal rigidity. In this manner also the maximum of strength is secured with the minimum of weight, while the outstanding advantages of the non-rigid and rigid types are secured with the reduction of the inherent disadvantages to the minimum. Finally, the new idea enables the stresses on the different members to be calculated easily, because they are definite.

From the passenger's point of view the feature which will arouse the greatest measure of interest is the provision of accommodation to meet his convenience. Aerial travel will never, at least not until development has been carried to a very advanced stage, be able to offer the level of spacious luxury identified with the contemporary liner, but it can extend the luxurious comfort incidental to railway travel as offered by the Pullman car. This is the model which has been accepted for the Atlantic airship. In the Admiralty craft the gondolas, in which are mounted the engines, are suspended from the triangular keels or backbone of the airship, the tunnel offered by this triangular girder system constituting the means of communication between the various gondolas and other parts of the vessel. In the Short-Mitchell aerial liner a long corridor-like apartment is suspended from the triangular girder keelson, and extending the full length amidships. This continuous apartment is 380 feet in length,

and rectangular in section, being 12 feet in width by 8 feet in height. It is completely enclosed, but the portholes with which it is freely provided offer uninterrupted views of the country beneath, and afford adequate natural illumination, supplemented by electric lighting.

At the extreme prow is the control cabin carrying the bridge, chart-house, and all instruments requisite for the navigation of the craft. The officers and crew have their quarters forward, thus being completely isolated from the passengers. Access to the various parts of the vessel, such as the stern engine-room, wing gondolas and their motors, as well as to valves and so forth, is provided by the crawling way, as the tunnel in the triangular girder system forming the backbone of the ship is called, and these facilities are provided at specific intervals to assure the efficient working of the ship.

Walking from stem to stern one passes from the crew's quarters into the drawing-room, measuring 30 feet in length by 12 feet wide, where there is seating accommodation for 30 passengers, the lounges and chairs being disposed to allow the space to be turned to best advantage. The drawing-room leads into the passengers' main sleeping quarters, which follows the broad principles of the Pullman sleeping-car of the American railways except that separate single-berth cabins are provided for each passenger. The sleeping space occupies the greater part of the available length of the passenger accommodation, being 150 feet in length and subdivided into four saloons. The two extreme saloons each have accommodation for eight passengers, while the two inner saloons will receive twelve passengers each. The sleeping cabins, which are single, instead of being upper and lower as upon the American railway cars, flank either side

of a central gangway, sufficiently wide to admit comfortable movement. The sleeping accommodation is permanent in character; that is to say, the saloons are not converted into lounges during the day as is the case with American railway Pullman cars.

Passing from the sleeping saloons one enters the dining saloon, capable of seating 56 passengers at the one sitting. The arrangement is similar to that followed in our railway dining cars, with tables set at right angles to, and on either side of, the central gangway, each table accommodating four passengers. This saloon measures 42 feet in length and leads into the aft sleeping saloon, having ten single berths. In the stern of the vessel is a smoke room, 32 feet in length, capable of seating 32 passengers, while at the extreme stern comes the aft engine-room, galley, and petrol store. The relatively limited space available for the convenience of passengers has been turned to the most efficient account, and, generally considered, is spacious, at least in the sense of length, while the degree of luxury extended will be found to exceed expectations. Moreover the views obtainable from the dining and lounge saloons are of the most extensive character, the windows being large continuous squares of glass.

In a rival proposal which has been elaborated for a trans-Atlantic airship the passenger accommodation is placed on top of the airship; but the designers of the Short-Mitchell vessel, after discussing the question in all its bearings, decided that the underslung position was preferable. In the first place, a more complete view is offered from beneath the ship than can be the case when the accommodation is placed on top, because, in the last-named instance the downward angle of vision, which is naturally the direction in which observation would want to be made, suffers interrup-

tion by the contour of the vessel itself. In the airship under review the passengers are able to obtain a direct vertical view if they so desire, while even when seated they secure just as wide and uninterrupted a view as is offered from a seat in a Pullman railway car.

Another and far more vital issue governed their decision. Hydrogen is continuously issuing from the gas-bags. It cannot be prevented. It is essentially due to the property of diffusion incidental to this gas which enables it to permeate the finest and most resistant fabric of which the gas-bags may be composed, while, of course, under expansion a certain quantity escapes automatically through the valves. The hydrogen, being lighter than the air, naturally ascends, although, of course, almost instantly after making its escape, it dissipates in the surrounding atmosphere. Nevertheless, when the passenger accommodation is placed on top of the airship, the surrounding air is likely to be somewhat highly charged with hydrogen. While this gas exercises no injurious effect upon the human body, and does not affect respiration in any way, it nevertheless constitutes a dangerous atmosphere, and one in which it would be exceedingly risky to have a naked light, even a match, because the air would be highly explosive. Consequently it would be hazardous to provide the travellers, when their accommodation is placed upon the top of the ship, with the opportunity to enjoy the company of My Lady Nicotine. On the other hand, by placing the passenger accommodation beneath the vessel enhanced safety is assured, while smoking-room amenities can be provided. No escaping hydrogen would haunt this low level so that indulgence in smoking might be followed with impunity. It will be remembered that in the case of the Zeppelin passenger-cruising aerial yacht

Deutschland the passenger cabins were placed beneath the vessel. This arrangement also facilitates embarkation and disembarkation, passengers being able to step directly from cabin to *terra firma* and vice versa.

The vessel which I have described has been designed essentially for trans-Atlantic travel, but similar principles would prevail in the elaboration of craft for longer trans-oceanic journeys, such as between London and South America, Vancouver and Japan, or London and Australia via India, the Straits Settlements and New Guinea. For these longer journeys far larger craft would be employed, and increased dimensions would enable more spacious passenger accommodation, as well as a more elaborate scale of luxury, to be introduced if desired; but in point of comfort the trans-Atlantic craft would leave nothing to be desired; certainly it would be comparable with the drawing-room scale incidental to Pullman railway cars. As travellers are quite prepared to tolerate confinement upon a railway Pullman for four or five days while crossing the North American continent, they would not object to similar accommodation over an aerial journey of 3,000 miles, which it is estimated would be covered in about 72 hours under normal weather conditions.

Such is the airship liner which has been designed and which is ready for construction the moment finance becomes sufficiently imaginative to realise the possibilities of trans-Atlantic aerial travel. A vessel of this type is likely to cost about £380,000, although, if the intentions of the designers based upon more recently acquired experience involving a larger craft were followed, the capital outlay would be nearer £500,000, but its carrying capacity would probably be increased to 100 passengers. A fleet of four vessels, the mini-

mum with which it would be possible to maintain a regular efficient service capable of bidding defiance to wind and weather and of satisfying commerce, would thus entail an expenditure of approximately £2,000,000.

In view of the magnitude of the capital investment involved, doubts might arise in the minds of the prudent as to whether such a service could ever pay. Upon this point no anxiety whatever exists in the minds of the designers. Mr. Mitchell, from his experience in connection with steamship travel, is convinced that more than a sufficient number of travellers would be steadily forthcoming who would be prepared to face a heavy tariff for the ability to travel by a fast airship. The speed attainable would be an irresistible attraction, because it would reduce the length of the interruption to business to only two or three days. Fortified with this knowledge he is convinced that sufficient passengers would be found for every trip, at £100 to £150 per head, to occupy the whole of the available passenger carrying accommodation. Upon this basis a ship could be expected to earn from £5,000 to £7,500 gross per trip, or from £10,000 to £15,000 each round passage. Upon the basis of thirty round trips per year each representing a total travelling time of seven days per round journey—in favourable weather the trip would be made quickly, while in bad weather it would suffer appreciable delay so that an average of 3½ days per single journey might safely be made—this would aggregate 210 travelling days per year, bringing in a gross revenue ranging from £300,000 to £450,000, or allowing only 75 per cent. available carrying capacity being occupied, £225,000 to £337,500 per annum.

The allowance of 210 days' travelling out of a possible 365 days may appear to be low, but one must not forget that certain time allowances would be necessary upon the com-

pletion of each single trip to take in fuel, water, provisioning and tuning-up, while upon the conclusion of the round trip a more elaborate overhaul of machinery would require to be made. The airship is still in its infancy; it cannot be placed on a parallel with the ocean liner, which is the sum of over a century's steady development and which is driven by machinery brought to a wonderful stage of perfection, reliability and efficiency. Still, even our greyhounds of the sea do not work the whole year round; they are withdrawn periodically from service for elaborate overhaul. The airship would need to be similarly tended, and would likewise have to be sent into dock at intervals of a few months to have her structure thoroughly examined, repaired where necessary, gas-bags overhauled, and outer covering re-doped. Consequently, all things considered, it would be doubtful whether a ship, such as I have described, would be able to put in more than 210 days of actual travelling during the year.

Even the running costs have been estimated with a fair degree of accuracy, and it is not likely that actual results would exceed the estimates in this connection. Fuel charges are known, as are also those of wages for crew, as well as provisions and other incidentals, steamship experience being of decisive value in this connection. Hydrogen can be safely estimated at 10s. per 1,000 cubic feet, the cost of initially inflating the 4,450,000 cubic footer, with which I have been dealing, coming out at £2,225, an insignificant sum in the circumstances. The only serious factor open to discussion is depreciation, and upon this issue authorities vary considerably, one estimating the life of the airship at three years. But Mr. Mitchell assumes a more optimistic opinion upon this subject. He does not see why an airship of improved design, properly tended, should not be able to offer ten years' steady

service at least. Upon this basis the depreciation factor would come out at about £38,000 per annum.

The span of life of the trans-Atlantic airship is not so likely to be affected by wear and tear as by risk of being superseded. Once development sets in in grim earnest a situation comparable with that which has prevailed upon the high seas for so many years past may safely be anticipated. Each succeeding vessel will be so much larger, faster and more luxurious than its predecessor, and the travelling public, as a rule, always patronises the last arrival. In this way depreciation might be enhanced, although it can be off-set by the levy of the maximum charges for the new vessel, graduating the fares according to the age of the liner and its degree of comfort and standard of luxury. For many years to come passenger accommodation upon airships is certain to be limited, and demand for berths, once the public has become assured that the way of the air is as safe as, and more comfortable as well as quicker than, the way of the sea, will exceed the supply. Accordingly the latest competitor for patronage will always be able to command what might even appear to be exorbitant fares if it does not even create new traffic. The question of fares, depreciation, and life of the vessel will undoubtedly adjust itself to the occasion. The spirit of competition must be fostered. In this way the negotiation of the Atlantic by air, in comfort and luxury, within 30 to 40 hours, under favourable conditions, will be achieved. As to what speeds will be recorded in the air with this type of craft it is dangerous to hazard any definite statement, but it is generally assumed that they will range from 80 to 90 knots maximum. The highest speeds will be attained by the aeroplane, which constitutes another and different story.

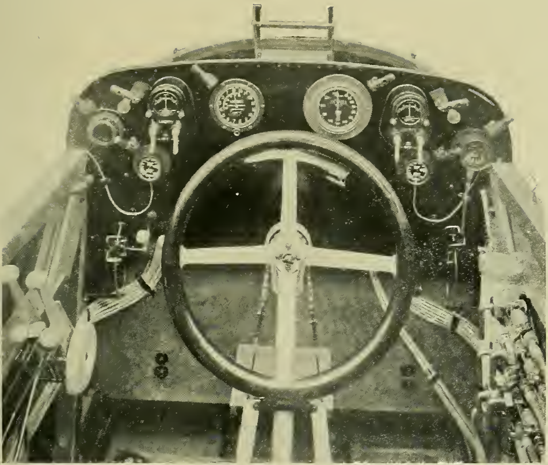
CHAPTER XX

The Aerial Mercantile Marine as a Profession

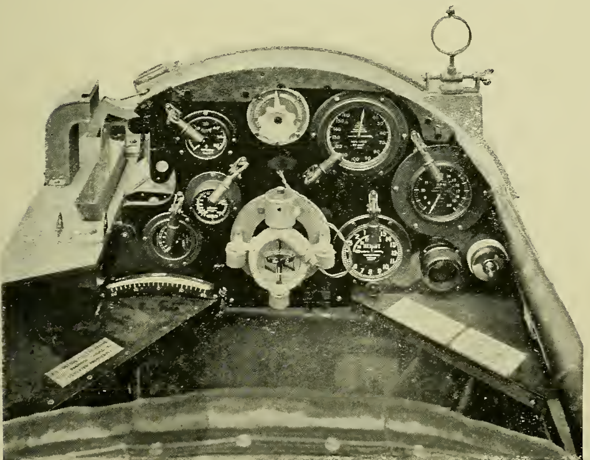
WITH the popularisation and development of commercial flying it is only logical to anticipate a desire upon the part of the boys and youths of to-day to enter this field in a professional capacity. How can I become an airman? Such is the question one hears on all sides.

At the present moment it must be frankly admitted that opportunity is strictly limited. The end of the Great War found the country possessed of a huge aerial force of 30,000 officers and 25,000 cadets in training. Such a force would be adequate to meet the needs of civilian flying for decades to come if the clock stood still, but Father Time waits for no man. Nevertheless many years will necessarily pass before the whole of these trained craftsmen, should they decide to continue to identify themselves with aerial transport, be absorbed.

What may be described as the Aerial Mercantile Marine can be subdivided into several branches. Pilots are required for aeroplanes and for dirigibles; mechanics are necessary to attend to the aeromotors; while other hands are essential for building and maintaining the structures of the two types of flying machine, as well as to staff aerodromes and the auxiliary departments identified with the maintenance of the way of the air, such as meteorologists, wireless operators, photographers, riggers, and so on.



A simple dashboard carrying instruments indicating air-speed, temperature of water in radiator, height indicator switches, and inclinometer. This illustration also shows the wheel mounted on joy-stick for control of lateral stability, the joy-stick itself being used solely for manipulation of the rudder.



Dashboard of aeroplane, showing instruments for ascertaining height, speed, engine revolutions, petrol and lubricating oil pressure, and inclinometer. In the centre is mounted the aviator's compass, showing the compass card floating in alcohol in a sealed bowl.

HOW THE AIRMAN FINDS HIS WAY IN THE AIR

Aerial Mercantile Marine as a Profession

The future development of civil or commerical flying is obscure at the moment, but there is reason to believe that the whole of the directing side of the question will be conducted by the Air Ministry as far as Great Britain is concerned. As is well known, this has been subdivided into two broadly defined departments—Service and Civilian flying, respectively.

The system which should be encouraged is obvious. Service needs are certain to be heavy, the intention at present being to maintain several squadrons in being. This will necessitate the creation of a huge force of pilots and navigators, part of which will need to be regarded as a reserve force. It will not be found possible, however, to employ the whole of this reserve force; consequently we should see the creation of a Royal Air Force Reserve to officer the commercial fleet, in the same way as our ocean liners offer an attractive field for the Royal Naval Reserve. In this way we should be assured of a highly efficient and live force available for national duty at a critical moment—one trained to the top notch of efficiency, of sustained skill, and wide experience.

If such a policy be followed then the door to the higher appointments in aerial service will be viâ the Service, and will lead to the creation of a force comparable with that incidental to the Navy and Army. Such a force is urgently demanded at the moment. We have few competent aeroplane designers, although the war appreciably added to their ranks, but they have been fully absorbed by commerce. Training for these appointments, the plums of the "flying" world, will follow lines far different from those that have been practised hitherto, and will only be available to those who have graduated through a stern school, working from the

bottom up. Piloting an aeroplane purely and simply is relatively easy, but in future the man at the wheel will need to be more than a mere joy-stick manipulator. He will need to be a master of a number of sciences, the compeer of the commander of an ocean greyhound, and at the same time of a plastic and receptive mind, willing to keep pace with progress. Training for such positions as these will be rigorous and difficult, while progress will be relatively slow, but the prizes to be won should be worthy of the training and comparable in calibre with the commissions obtainable in the other Services.

Of course, it is only reasonable to anticipate that, as time passes, we shall witness the arrival of the aerial counterparts of the ocean tramp and coasting vessels, the positions upon which will be open to those who have not passed through the official portals, but who have earned their "ticket" from the Air Ministry by progressive examinations. The expense entailed in gaining the position of control of the "air-jammers," or aerial tramps, will not be so expensive as that entailed in rising to command of an express aeroplane or ocean-going dirigible, while probably the remuneration will prove to be less attractive. Yet the knowledge which it will assimilate will be every whit as diverse and profound.

Manufacturers will undoubtedly maintain pilot and commanding staffs of their own, but as time proceeds undoubtedly they will come to depend for their requirements upon the men who have graduated through the Service. To a certain degree they will raise and develop their own pilots, notably for testing purposes, which is a branch of the craft distinctly apart, and which demands a more than passing experience of the handling of the plane and its possible

whimsicalities. It is from the results of the test of the new model that the designer receives confirmation of the practicability of his ideas. With the elaboration of constitutional laws, however, gained as a result of scientific and technical mastery of the problems involved, the task of the tester is certain to become less risky, except in connection with machines designed essentially for military and naval service.

Our colleges and educational institutions are devoting wider attention to the air in its relation to transport, although it is to be feared that those associated with these enterprises are disposed to display a somewhat parsimonious attitude towards the members of their staffs in regard to emolument. One of our rising aeroplane technicians related to me a personal experience in this connection. He had graduated through college, making a special study of aeronautics, aero-dynamics, and the allied sciences, and had passed through his examinations with flying colours. The war extended him a certain opportunity to turn his talents to advantage, his abilities being freely recognised. But with the cessation of hostilities came the chance to continue the investigations and research in the channels which made such profound appeal to him. But the reward offered, namely, £250 a year, represented but a poor return for the heavy expense he had incurred in the acquisition of his knowledge. The outlook being so inadequate, the flying machine enthusiast promptly crushed all ambitions to excel in the new science. The realm of the air was abandoned for another branch of commerce which offered far more attractive possibilities. Aero-dynamic research and investigation, so far as he is concerned, has been definitely abandoned. If we desire to aspire in the realm of the air we shall need to be

far more generous in our appreciation of brain-power than is the case to-day, although the above treatment is typical of our attitude towards the technician.

In so far as the purely mechanical side is concerned, the scope for ability is equally narrow at the moment. The aeromotor, being an offspring of the motor-car engine, graduation through the works identified with the latter industry may be regarded as the natural stepping-stone to the aerial realm. But here again a brain of a different type and level is demanded, one involving not only knowledge of design, but of metals and resource, to assist in the acquisition of a higher degree of efficiency, reliability and durability. At the moment the openings for pioneering are not brilliant, unless it be in connection with the evolution of a new type of prime mover. The high-speed internal combustion engine, as evolved for the aeroplane and dirigible, more especially the former, appears to have been brought to the limit of its development. It is not the ideal engine for the aeroplane, but at the moment is that most closely coinciding with requirements—hence its utilisation. Brilliant minds are seeking for a more efficient system of generating power, one comparable in weight per horse-power, but less susceptible to easy derangement. The gas turbine represents one promising field of development, while the wireless transmission of energy is likewise arousing considerable attention. The electric motor would be ideal for aerial duty were it possible to draw upon some outside source of conserved electric energy. In the present stage of knowledge it cannot be used, because although its efficiency is high the necessity to rely upon accumulators rules it out of application, owing to questions of weight and limited radius of action per charge.

It is for this reason that more concentrated effort is being expended upon the wireless transmission of energy. And we are probably within more reasonable reach of this achievement than may be popularly supposed. The French have already been able to record some startling achievements in this direction, having succeeded in piloting and driving an aeroplane from the ground, with energy supplied from a land station, over varying distances.

The possibility of the electric motor displacing the present aeromotor opens up vistas of enormous significance. Such an aeromotor will bring the electrical engineer into the aerial field in a hundred and one different ways. Control will be reduced to the simplest task—the movement of a single lever. It will revolutionise aerial movement as completely as it has transformed railway travel, enabling far higher speeds than have yet been recorded to be attained; but this is a field, at the moment, for the inventor both trained and untrained, if such a term may be employed, in the demands of the air, but it is one of distinct promise for the simple reason that it will throw the gates of knowledge open far wider.

Coming to the actual design and construction of the aeroplane itself it is obvious that many developments are possible in this direction. Wood will give way to metal as a structural material, and this in turn will stimulate the science of metallurgy, more particularly in its application to the air, where extreme strength combined with lightness is so imperative. We are even destined to witness the utilisation of metal instead of linen for wings, in which direction some notable strides are to be recorded. As a matter of fact, one of our leading aeroplane designers has expressed the opinion that by 1921 metal will have displaced fabric in this connection, which will represent a revolution

of no mean order, and may lead to a complete revision of our prevailing notions concerning the flying machine.

While inventiveness was encouraged under the pressure of war it was fostered along somewhat well-defined lines to meet the needs of the moment. There was not time to carry out the extended test which is possible and imperative under peace conditions. Consequently, much of what was learned during the five years of hostilities will need to be forgotten. In these circumstances the achievements and line of thought followed in connection with the conquest of the air in the past offers no reliable criterion of the trend of things in future. Quite a new type of "flying" engineer, pilot, navigator and commander, as well as designer, will be required. At the moment the indications are somewhat vague. Development is being conducted along lines which at present lack definition, so that it is somewhat difficult to narrate emphatically precisely what openings will obtain for those who wish to follow aerial operations in a professional capacity. But this much is certain. It will become a field for the privileged and diligent worker; will create a type which at the moment is non-existent.

Now that more leisurely methods can be practised, more severe discrimination of the human material will undoubtedly prevail. War has enabled a mass of statistics to be gathered, the resolution of which must prove of assistance in this respect. From the material thus obtained it has been found that the strain inseparable from flying falls almost entirely upon the nervous system, which must be strikingly tough to withstand the ordeal. Of course, it is also imperative that the heart and lungs and other organs should be perfectly sound, because they are subjected to imposing strains due to rapid and extensive variations in air pressure and density

arising from change of altitude. It has been advocated that the initial medical examination should not only be of a most searching character, but that further examinations should be conducted at intervals to ensure a continuance of physical and nervous fitness.

Many interesting forms of apparatus have been devised to assist in the selection of men to serve as pilots and to determine their fitness for this responsible post. Among these may be mentioned the mercurial manometer having a rubber tube and mouthpiece. The candidate is instructed to take a deep breath, and then to expend the expiatory effort through the tube. In this way he should be able to force the mercury up to a pressure of 40 millimetres and to hold it at that point for 40 seconds. While thus engaged a reading of the pulse is taken at intervals of 5 seconds and the results recorded. Another interesting process is to time the interval occupied in thinking and responding to a signal, a stop watch being used for this operation. Flying depends upon quick and decisive action, especially when it is remembered that the flying machine may be travelling at 150 to 200 feet per second.

It is also incumbent that one should possess what may be described as the flying temperament. Some pilots are to the manner born; they take as naturally to the air as a duck takes to water, are fearless, and after a short period of acclimatisation to the new conditions, appear to become invested with a sixth—flying—sense. In some cases this "instinct" appears to be developed; in others it is latent and demands careful incubation as it were. This is the reason why the Air Ministry to-day is making such efforts to catch the fledgling young—at about fifteen years of age—experience having proved that if taken in hand at this age and submitted to the

correct training he is excellent raw material, allowing all the essential requirements necessary to yield a first-class pilot to be developed to their utmost. The "life" of an active pilot is somewhat speculative, sufficient experience not having been accumulated in this connection to allow a reliable and conclusive impression to be formed. War experience in this connection is of no practical value, owing to the abnormal pressure at which flying was conducted, the need for intensive training, incomplete development and the intense strain imposed upon the nervous system. Under peace conditions, which are certain to be less strenuous, it is anticipated that the period of serviceability will be about 15 years, there being few men whose physique and nervous system will allow them to remain in a responsible position in the air after reaching thirty years of age. Of course, such men upon the conclusion of air service, would be invaluable for the fulfilment of ground duties, many of which are quite as exacting as those incidental to the air, and to serve in the capacity of instructors.

Nevertheless, the issue concerning the span of serviceability of a pilot is decidedly uncertain. The flying machine must undergo considerable evolution. That of 1935—fifteen years hence—will probably be found to have as little resemblance to its prototype of 1919, as does the contemporary ocean liner bear to the *Comet*. Progress, at the moment, in the world of flying is advancing at an extraordinarily rapid rate and cannot fail to exercise a corresponding influence upon the personnel.

Printed by Cassell & Company, Limited, La Belle Sauvage, London, E.C.4
F50.919